VOLUME LXXIX NUMBER 2

JUNE, 1953

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PUBLISHED BY THE AMERICAN ENTOMOLOGICAL SOCIETY AT

THE ACADEMY OF NATURAL SCIENCES

PHILADELPHIA

THE AMERICAN ENTOMOLOGICAL SOCIETY

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Founded 1859 Incorporated 1862

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THE PATTERN OF SPECIALIZED HEAT-SENSITIVE AREAS ON THE SURFACE OF THE BODY OF ACRIDIDAE (ORTHOPTERA) PART I. THE MALES

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(Plates I–XVII, text-figures)

In 1951 the writer reported that certain structurally specialized areas on the surface of the head, thorax and abdomen of the African migratory locust, *Locusta migratoria migratorioides,* were particularly sensitive to heat and that it was probable that they were influential in determining the characteristic orientation shown by this species in sunlight. A survey of the literature on the behavior of locusts and grasshoppers when exposed to a source of heat, either under field conditions or in the laboratory, gave strong support to this tentative conclusion. The papers of Grassé (1922) *, Parker (1924), Geist (1928), Fraenkel (1929, 1930) and Volkonsky (1939) were especially valuable and the present writer has been able to confirm many of the observations described in them and to extend them to additional species.

It soon became apparent that information concerning the occurrence of these sensitive areas in other species of Acrididae might disclose interesting correlations between their presence and the habits and habitat of the various species. With the help of many other workers material was obtained from North America, Central America, South America, Europe, Africa, Asia and Australia. Six subfamilies were represented—Pamphaginae, Pyrgomorphinae, Acridinae, Oedipodinae, Romaleinae and Cyrtacanthacridinae—and many types of habitat—cultivated fields, pastures, prairies, grasslands, deserts, woods, seashore, drainage ditches, marshes, riverbanks, mountains, etc. Of the species examined all,

* A list of references will be included in Part II of this paper, which will be published in an early number of this journal.

with one interesting exception, were found to possess the specialized areas. The differences between males and females are so marked that it has been decided to present the results for the males in this paper and those for the females in a second.

Materials and Methods

The grasshoppers and locusts used in the present study were specimens which had been preserved in fluid (Bouin's solution, formalin, alcohol, etc.) and the author is indebted to many persons for assistance in obtaining and identifying them.[1]

Usually a single male of a species was examined but in several instances two or three were studied and in one case 25 specimens of the same species were compared (Slifer, 1954b). Each individual was measured before dissection and its *length* (anterior surface of the face to posterior tip of the abdomen), *width* (metathoracic sternum just anterior to the metathoracic coxae), and *height* (mesothorax just anterior to the mesothoracic coxae) recorded. The legs and wings were removed and laid aside and the head, thorax and abdomen separated from each other. These last three parts were subdivided further and the pieces resulting soaked in a warm, concentrated solution of potassium hydroxide until the epidermal cells, muscles, fat body, tracheae, etc. could be easily removed from the cuticular layer. The pieces of cuticle were washed and cleaned in distilled water and then examined, under a dissecting microscope in reflected light, in order to locate the silvery areas which are characteristic of the heat-sensitive spots.[2] Each

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[1] The present study would have been impossible without the generous assistance of many other workers who provided material and advice. Among these were Dr. B. P. Uvarov of the Anti-Locust Research Centre in London; Dr. R. L. King of this Department; Dr. K. H. L. Key of the Commonwealth Scientific and Industrial Research Organization of Canberra, Australia; Dr. E. Burtt of the East African Tsetse Research Organization, Old Shinyanga, Tanganyika Territory; Mr. W. J. Stower of the Desert Locust Survey, Asmara, Eritrea; Mr. H. A. F. Lea, Chief Locust Officer, of Pretoria, South Africa; Mr. J. A. G. Rehn of the Academy of Natural Sciences of Philadelphia; Dr. W. H. Stickler of Florida State University, Tallahassee, Florida; Dr. E. Helwig of the University of Colorado, Boulder, Colorado; and the late Dr. F. B. Isely of Trinity University, San Antonio, Texas.

[2] It should be emphasized that if heat-sensitive areas which lack a silvery cuticle are present—and there is some evidence that such occur in the Acrididae (Slifer, 1951)—they will not be discovered with the method employed here. Their detection would be extremely difficult with any technique presently available.

piece of cuticle which contained one or more of these areas was flattened in water and under a cover-glass on a microscope slide. The outlines of the special areas were then drawn with a camera lucida and the area inside each outline measured with a planimeter.

After the total area of the heat-sensitive spots had been calculated for an individual the percent of that total which was present on each region of each body part was determined. The results are presented in the form of histograms on plates I to XVII. In each histogram a base-line, marked zero, has been divided into thirteen equal parts which represent, in order and from left to right, the head, prothorax, mesothorax, metathorax and abdominal segments one to nine. The rectangles which extend vertically above the base-line represent dorsal heat-sensitive areas and those which extend below it represent ventral areas. In a few individuals sensitive areas are present on the sides of the abdominal terga close to the spiracles. These are represented in the figures by parallelograms which slant towards the right so that they can be distinguished from those heat-sensitive areas which lie close to the dorsal mid-line. The height of each rectangle or parallelogram indicates that percentage of the total sensitive area which is present on a particular part. Histogram patterns obtained in this way have been shown to vary within rather narrow limits for a single species (Slifer, 1954b).

The total body surface area of each specimen was calculated from the linear measurements made before dissection with the help of the formula

$$Y = 21 + 1.1\ (lw + lh + wh)$$

where Y equals total body surface (exclusive of that of the legs and wings), l equals length, w equals width and h equals height (Slifer, 1954a). The percentage of the total body surface which was modified as heat-sensitive was then determined from this value and that which had been obtained from the sum of the planimeter measurements of the special areas. As was pointed out in another paper (Slifer, 1954b) the percentage of the total body surface which is specialized as heat-sensitive varies rather widely for individuals of a species and so provides a much rougher index for the comparison of species than does the distribution pattern

described in the preceding paragraph. In comparing the species of the six subfamilies studied here this value has, accordingly, been assigned less weight than have the factors which determine the pattern, i.e., number of special areas and number of body parts which possess them. The terms used earlier for the specialized areas or spots (Slifer, 1951)—*antennal crescents,* which lie close to the antennal membrane on the head, and *fenestrae,* for those found elsewhere—will be employed in this paper.

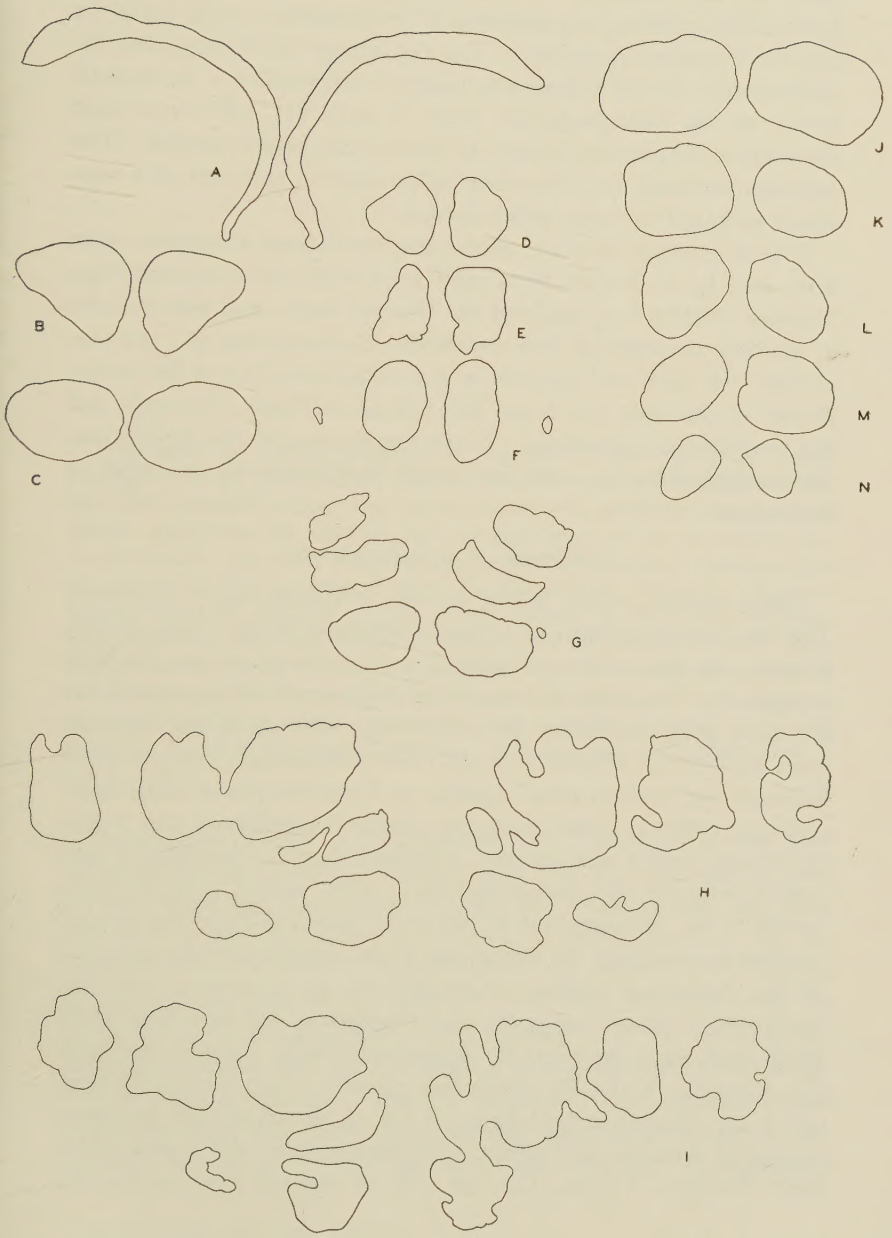
In thirteen individuals studied one member of a pair of fenestrae was absent. This unilateral condition was found only for very small spots—usually the smallest present on the insect—and involved, at the most, no more than 1.5% of the individual's total heat-sensitive area.

Results

Subfamily Pamphaginae

A single representative of this subfamily, *Saussurea stuhlmanniana,* from Shinyanga, Tanganyika, was studied but it proved to be an extremely interesting species. The male has 14 pairs of heat-sensitive areas and these are widely scattered over the body. Eight pairs are located on the dorsal surface and the rest are ventral. For the single specimen studied 0.91% of the total body surface was occupied by these special spots. Additional data for this individual are included in table 1 and the histogram prepared for it is presented in figure 1. As may be seen in text-figure 1 the fenestrae on abdominal terga 4, 5 and 6 of *Saussurea stuhlman-*

Text-figure 1.—Outline drawings of the heat-sensitive areas of a male *Saussurea stuhlmanniana* (Karsch) from Shinyanga, Tanganyika. A, antennal crescents, which partially encircle the antennal sockets; B, prothoracic (cervical) fenestrae, which lie in the cervical membrane near the anterior edge of the first prosternal plate; C, mesothoracic fenestrae, which are located near the anterior border of the scutum in the dorsal mid-line; D, fenestrae in dorsal mid-line of first abdominal segment; E, same for second segment; F, same for third segment; G, same for fourth segment; H, same for fifth segment; I, same for sixth segment; J, fenestrae near anterior, lateral edge of sternum of second abdominal segment; K, same for third segment; L, same for fourth segment; M, same for fifth segment; N, same for sixth segment. Compare with histogram, plate I, fig. 1. × 23.



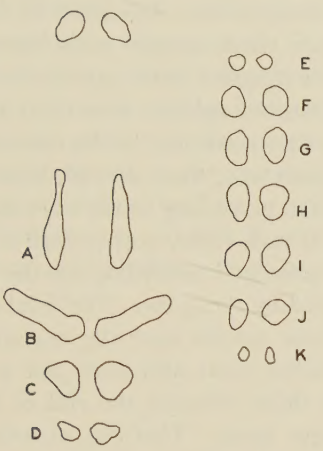
Text-figure 1

niana are each broken into several parts. This is a most unusual feature and nothing approaching it in complexity was found in any other species examined. The occurrence of fenestrae on the undersurface of the abdomen of males is uncommon. An examination of the histograms on plates I to XVII will show such fenestrae to be present in only 12 of the 122 species studied. The antennal crescents of *Saussurea,* in contrast to this, are of a type which is found in many other species.

It is of interest to note, since these specialized structures have been seen by so few of those who work with the Acrididae, that Thomas (1952) in a study of the thoracic body wall and muscles of another member of this subfamily, *Lamarckiana* sp., has described two thin oval patches in the dorsal mid-line of the mesothorax of the male (p. 2 and fig. 5, o.p.). These, obviously, are the mesothoracic fenestrae. None are shown on the metathorax and *Lamarckiana* sp. and *Saussurea stuhlmanniana* are alike in this respect.

Subfamily Pyrgomorphinae

Seven species which belong to this subfamily were examined. The heat-sensitive areas of a male *Pyrgomorpha* sp., from Keren, Eritrea, are shown in text-figure 2 and its histogram may be seen in figure 6. The antennal crescents of this individual, and of the six other pyrgomorphine species as well, were distinctly different from those of all members of the other subfamilies. In the three different but undetermined species of *Pyrgomorpha* a small heat-sensitive spot lies just above the antennal membrane and below the lateral ocellus and another is located close to the anterior and ventral edge of the compound eye. This second spot is, thus, *lateral* to the antenna and so quite far removed from the medial position occupied by the lower end of the crescent in the majority of the Acrididae studied. *Chrotogonus* sp. possesses only the uppermost of these two spots and *Phymateus pulcherrimus* has a third small spot between the upper and lower ones on the face. The fenestrae of the *Pyrgomorpha* sp. male, from Keren, Eritrea, which are figured in text-figure 2 are all dorsal except for those associated with the prothorax. Another species of *Pyrgomorpha,* from Wachiro, Eritrea, has one pair of ventral fenestrae on the



Text-figure 2.—Outline drawings of the heat-sensitive areas of a male *Pyrgomorpha* sp. from Keren, Eritrea. A, two-parted antennal crescents each with a dorsal portion lying above the antennal membrane and a ventral portion lying near the anterior and ventral corner of the compound eye; B, prothoracic (cervical) fenestrae, which lie in the cervical membrane just in front of the first prosternal plate; C, mesothoracic fenestrae, which are located near the anterior border of the scutum in the dorsal mid-line; D, metathoracic fenestrae, which are located near the anterior border of the scutum in the dorsal mid-line; E, fenestrae in dorsal mid-line of second abdominal segment; F, same for third segment; G, same for fourth segment; H, same for fifth segment; I, same for sixth segment; J, same for seventh segment; K, same for eighth segment. Compare with histogram, plate I, fig. 6. × 26.

abdomen (fig. 4) and a third species of *Pyrgomorpha,* also from Wachiro, Eritrea, has two ventral pairs (fig. 5). As may be seen by examining the histograms on plate I *Pyrgomorphella arachidis* and *Tanita* sp. each have six pairs of ventral fenestrae on the abdomen and *Phymateus pulcherrimus* has seven. *Chrotogonus* sp., as does the first of the three *Pyrgomorpha* sp. mentioned, has no fenestrae on the underside of the abdomen. It was noted in the preceding section that the occurrence of ventral abdominal fenestrae in males is unusual. Their presence in the Pamphaginae and Pyrgomophinae may have some special significance which is not apparent to the writer who has never seen a living representative

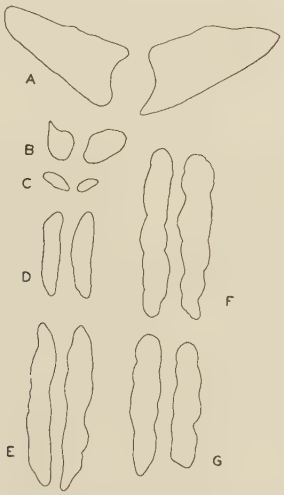
of either of these subfamilies. It would be interesting to know, for instance, whether those species with fenestrae on the underside of the abdomen frequent bare, sun-warmed earth or rocks.

In table 1 the Pyrgomorphinae examined have been arranged, *first,* in ascending order according to the number of pairs of special areas which each possesses; then, *second,* those with similar numbers have been ranked according to the number of body parts with such spots on them; and, *third,* within each of these divisions the species have been arranged according to the percentage of total body surface occupied by the spots. The final arrangement is such that, in general, those species near the beginning of the list have the fewest and smallest spots and these not so widely distributed on the body as do those towards the end of the list which, also, have more and larger spots. This list, as well as those presented below for the other subfamilies, must be considered as a first approach to a better arrangement which can be worked out only when we have more definite information concerning the relative importance of the several criteria used here to construct the lists.

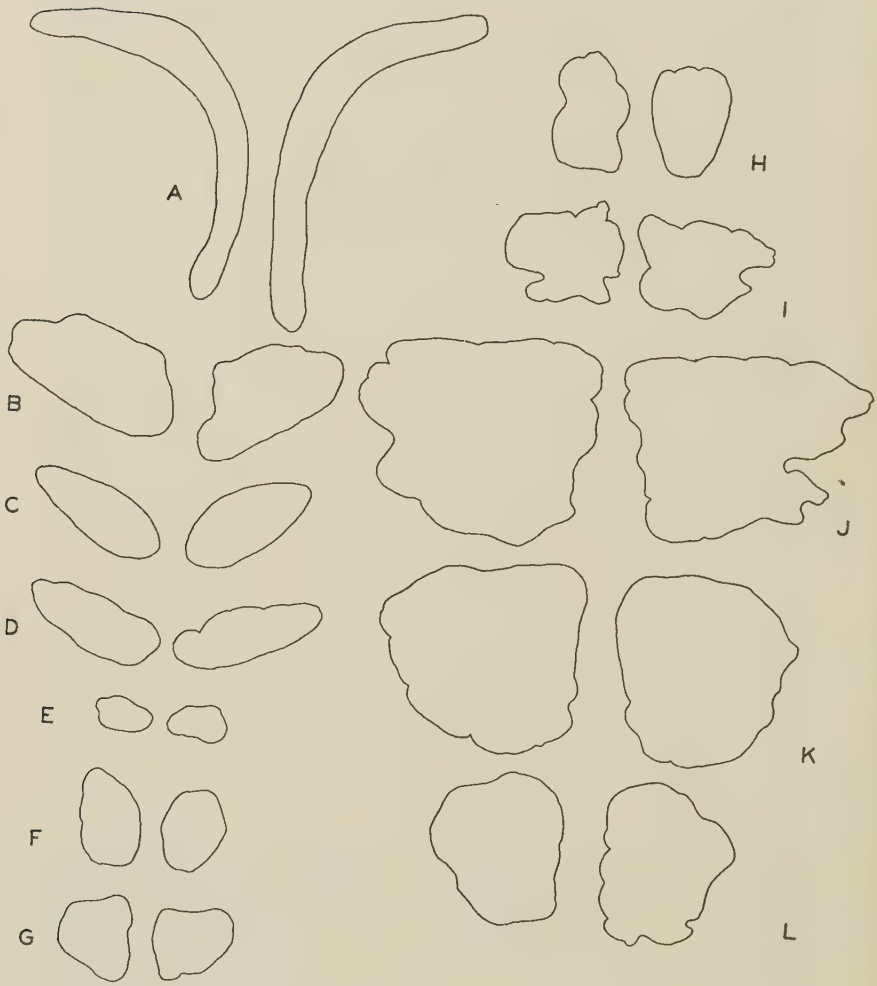
Subfamily Acridinae

Twenty species belonging to this subfamily were included in the present study. A male *Acrida bicolor,* from Cum Ceua, Eritrea, was selected to represent the group and its fenestrae are outlined in text-figure 3. The absence of antennal crescents is a surprising and conspicuous feature. Two other undetermined species of *Acrida,* one from Shinyanga, Tanganyika (fig. 10) and the other from Canberra, Australia (fig. 11) also lack crescents. Three other species—*Ageneotettix deorum* (fig. 12), *Chorthippus longicornis* (fig. 17) and *Neopodismopsis abdominalis* (fig. 25), all North American forms—also are without crescents but the fourteen other species of Acridinae examined each have them. The absence of prothoracic (cervical) fenestrae in *Ageneotettix deorum* (fig. 12), *Amphitornus coloradus coloradus* (fig. 13), *Chorthippus longicornis* (fig. 17) and *Neopodismopis abdominalis* (fig. 25) separates them, with one exception, from all other male Acrididae examined, for these particular fenestrae are more commonly present than any other pair of these specialized areas.

In table 2 the Acridinae studied have been arranged as were the Pyrgomorphinae in the preceding section. It will be noted that the number of pairs of spots tends to be fewer and their relative total size less than in members of the Pamphaginae and Pyrgomorphinae. Fewer body parts bear the structures and in none of the males were fenestrae found on the underside of the abdomen. As a group, then, the Acridinae tend to be poorly provided with these heat-sensitive structures. This will still be found to hold after the Oedipodinae and Cyrtacanthacridinae have been considered.



Text-figure 3.—Outline drawings of the heat-sensitive areas of a male *Acrida bicolor* (Thunb.) from Cum Ceua, Eritrea. A, prothoracic (cervical) fenestrae, which lie in the cervical membrane near the anterior edge of the first prosternal plate; B, mesothoracic fenestrae, which are located near the anterior border of the scutum in the mid-dorsal line; C, metathoracic fenestrae, which are located near the anterior border of the scutum in the dorsal mid-line; D, fenestrae in dorsal mid-line of second abdominal segment; E, same for third segment; F, same for fifth segment; G, same for sixth segment. Compare with histogram, plate II, fig 9. Note absence of antennal crescents. × 23.



Text-figure 4.—Outline drawings of the heat-sensitive areas of a male *Dissosteira carolina* (Linn.) from Iowa. A, antennal crescents, which partially encircle the antennal sockets; B, prothoracic (cervical) fenestrae, which lie in the cervical membrane near the anterior border of the first prosternal plate; C, mesothoracic fenestrae, which are located near the anterior border of the scutum in the dorsal mid-line; D, metathoracic fenestrae, which are located near the anterior border of the scutum in the

Subfamily Oedipodinae

Forty-six species of the subfamily Oedipodinae were examined. These, with a single exception, form a remarkably homogeneous group. The crescents and fenestrae of a male *Dissosteira carolina,* from Iowa, are shown in text-figure 4 and the histogram for this species appears in fig. 45. A small pair of fenestrae is present on the metasternum and because of this the species is not quite typical for the subfamily. *Hippiscus rugosus* (fig. 53) has a pair of fenestrae in the same position and *Trimerotropis pallidipennis pallidipennis* (fig. 78) has fenestrae here and on the mesosternum as well. *Arphia xanthoptera* (fig. 39) has mesosternal and metasternal fenestrae and still another ventral pair on the first sternal plate of the prothorax. *Austroicetes pusilla* (fig. 40) differs from all other species of Oedipodinae examined in having no antennal crescents. In this respect it closely resembles certain species of Acridinae described in the section preceding this.

The antennal crescents of six other species require special comment. In *Acrotylus variegatus, Camnula pellucida* and *Trachyrhachis kiowa fuscifrons,* the crescents are quite small and each consists of a single oval or oval-elongate piece lying between the lateral ocellus and the dorsal edge of the antennal membrane. *Derotmema haydenii laticinctum, Pardalophora apiculata, Psinidia fenestralis fenestralis* and *Rehnita gracilipes* are remarkable in that their antennal crescents are divided into an upper and a lower portion. These two parts, however, lie in the region usually occupied by the crescents in the majority of species belonging to the family and so are quite unlike the two-parted crescents described for the Pyrgomorphinae. An *Aiolopus* sp. male from Asmara, Eritrea and a male *Pycnodictya miniatiapennis* from Tanganyika were unusual in that in each the left crescent was in a single piece while the right was divided into two.

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dorsal mid-line; E, metathoracic fenestrae, which are located near the posterior border of the basisternum in the ventral mid-line; F, fenestrae in dorsal mid-line of the first abdominal segment; G, same for second segment; H, same for third segment; I, same for fourth segment; J, same for fifth segment; K, same for sixth segment; L, same for seventh segment. Compare with histogram, plate VII, fig. 45. × 36.

In table 3 the Oedipodinae studied have been arranged as were the species of other subfamilies in tables 1 and 2.

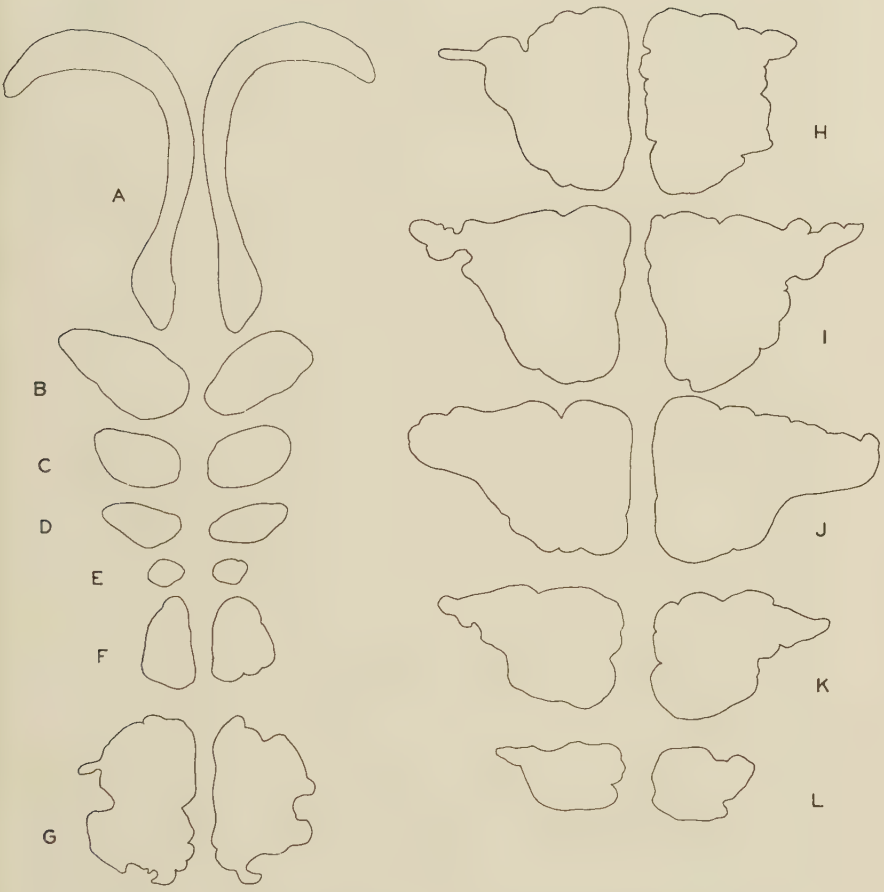
Subfamilies Romaleinae [3] *and Cyrtacanthacridinae*

Forty-six representatives of the Romaleinae and Cyrtacanthacridinae were studied. The antennal crescents and fenestrae of a male *Osmilia* sp., from Yurimaguas, Peru, are shown in text-figure 5 and it is apparent that they resemble those of *Dissosteira carolina* rather closely. The subfamily Cyrtacanthacridinae, however, is a far more heterogeneous one than is the Oedipodinae. At one extreme lies *Kosciuscola tristis,* the only acridid species in which no specialized heat-sensitive areas were found, and at the other *Catantops curvicercus,* with 1.77% of its total body surface occupied by such areas.

Two-parted antennal crescents, similar to those described for several oedipodine species, were found in *Melanoplus flavidus flavidus, Melanoplus infantilis, Melanoplus mexicanus mexicanus* (one side only), *Paratylotropidia brunneri, Phoetaliotes nebrascensis* and *Schistocerca alutacea. Kosciuscola tristis,* of course, has none since it lacks spots entirely. The large crescents of *Tetrataenia surinama* are conspicuously different from those of all other males seen for they extend ventrally on *both* sides of the antennal membrane, instead of medially only, and form a horseshoe-shaped structure.

In a single species, *Brachystola magna,* a pair of fenestrae is present on the first prosternal plate (fig. 79). Such were described in the preceding section for *Arphia xanthoptera.* Ventral fenestrae were found on the mesothorax of *Cyrtacanthacris tatarica tatarica* (figs. 86, 87) and *Nomadacris septemfasciata* (fig. 112) and on the metathorax of *Caloptenopsis meruensis* (fig. 82). In *Catantops axillaris* (fig. 83), *Catantops curvicercus* (fig. 84) and *Catantops* sp. (fig. 85) they are present on both the mesothoracic and metathoracic sterna. Seven large pairs of fenestrae were found on the underside of the abdomen of *Brachystola magna* (fig. 79). *Cyrtacanthacris tatarica tatarica* (figs. 86, 87), *Hesperotettix speciosus* (fig. 89) and *Paraidemona punctata* (fig.

[3] According to Roberts (1941) the genera *Brachystola* and *Romalea* should be placed in a separate subfamily, the Romaleinae. The characters studied here would further justify such a separation.



Text-figure 5.—Outline drawings of the heat-sensitive areas of a male *Osmilia* sp. from Yurimaguas, Peru. A, antennal crescents, which partially encircle the antennal sockets; B, prothoracic (cervical) fenestrae, which lie in the cervical membrane near the anterior border of the first prosternal plate; C, mesosternal fenestrae, which are located near the anterior border of the scutum in the dorsal mid-line; D, metathoracic fenestrae, which are located near the anterior border of the scutum in the dorsal mid-line; E, fenestrae in the dorsal mid-line of the first abdominal segment; F, same for second segment; G, same for third segment; H, same for fourth segment; I, same for fifth segment; J, same for sixth segment; K, same for seventh segment; L, same for eighth segment. Compare with histogram, plate XV, fig. 113. × 31.

114) each have a single pair in this region and *Locheuma brunneri* (fig. 92) has two ventral abdominal pairs. *Catantops curvicercus* has a very small, single, median spot near the anterior border of the fourth and fifth abdominal sterna (fig. 84). The male *Romalea microptera* is distinguished from all other males examined by the possession of a pair of lateral abdominal fenestrae (fig. 121). These are located on the third abdominal tergum close to the spiracles. Lateral fenestrae of this type are common in female Acrididae but this is most unusual for a male. *Hypochlora alba* differs from all other males in still another way for it has no abdominal fenestrae of any kind (fig. 91).

Eighteen species of the genus *Melanoplus* were studied and their histograms (figs. 94 to 111) resemble one another rather closely. The five species of *Schistocerca* (figs. 122 to 127) are a particularly interesting group for the several specimens studied came from North America, South America, Africa and Europe (laboratory-bred). In each of these six males the dorsal pair of fenestrae on the fourth abdominal segment is either absent or distinctly smaller than the pair on the third and fifth segments. Although this was also noticed in certain other genera it is not a common condition.

All of the species of this subfamily which were examined are listed in table 4 and the system of arrangement described earlier is followed.

Discussion

Until careful observations have been made of these and other species of Acrididae in the field and in the laboratory under various conditions of radiation, few satisfactory conclusions as to the significance of the amazing variety of heat-sensitive spot patterns within the group will be possible. The universal occurrence of the spots—*Kosciuscola tristis* only excepted [4]—suggests that their role must be an important one. It is possible that some correlation may exist between a pattern of a certain type and the habits of the species which possesses it or the habitat in which it is found. As yet, however, available information about the precise behavior

[4] Key and Day (personal communication) have discovered a novel and interesting type of temperature response in this species and will report their results in an Australian journal.

of the individual in a particular micro-habitat either does not exist or is very scanty for most species. A statement by Parker (1929 p. 331) is of interest here. He says that: "Since there is sometimes a difference of 40° F between the soil surface and the air 2 inches above the ground, a grasshopper is able to choose its own temperature by merely moving an inch or two up or down a blade of grass." It is not enough, then, to know, to quote another writer, that a certain species is found in "grassy tangles bordering cultivated fields." Much more detailed information is needed. Observations of the type made by Volkonsky (1939) would be especially helpful. It is the present author's hope that the data presented here may be used by other investigators, particularly those who have the opportunity of watching some of these species under natural conditions, in an attempt to correlate particular spot patterns with various types of behavior and habitat. This whole field of investigation is a new one and almost completely unexplored.

Since so much of the needed information is lacking—and probably will be for a long period for most of these species—it may be helpful to point out certain possible correlations with particular patterns. If the following speculations stimulate even a few investigators to obtain additional evidence which will either prove or disprove them they will have served their purpose.

Spot Pattern and the Male Reproductive Organs.—It was suggested earlier, in the studies on *Locusta migratoria migratorioides* (Slifer, 1951), that the presence on the fifth abdominal tergum of the male of the largest of all the fenestrae might have a special significance since the testes and seminal vesicles lie close below the body wall in this region and it is well known that insect spermatozoa are especially susceptible to damage by high temperatures. This suggestion, based on a single species, is strongly supported by the findings in the present study. In 102 of the 122 species examined the largest fenestrae were found on the fifth abdominal tergum. In three specimens the fenestrae on segment 4 were the largest and in nine those on segment 6. In 114 specimens, or 93%, then, the fourth, fifth and sixth segments are better provided with these special areas than is any other body region. In

five of the remaining species fenestrae are present in this position even though they are surpassed in size by those elsewhere. The only species which lack fenestrae on the fourth to sixth abdominal terga are *Kosciuscola tristis, Hypochlora alba* and *Pyrgomorphella arachidis. Kosciuscola* has no special heat-sensitive areas on the entire body so far as is known and *Hypochlora* has none on the abdomen. *Pyrgomorphella* has no fenestrae on the dorsal surface of the abdomen but is very well provided with them ventrally. It seems improbable that a condition found with such constancy in so many species should not have an important biological significance. The protection of the spermatozoa from excessive heat may well be their function.

Spot Pattern and Wing Development.—Another interesting association found in a number of species is that between the apterous or brachypterous condition and the presence of ventral fenestrae on the abdomen. Of the species considered in this paper only one, *Paraidemona punctata,* is completely apterous and its spot pattern is of a common type except for the presence of a very small pair of fenestrae on the underside of the second abdominal segment. The males of 104 of the species are macropterous and of 17 are brachypterous. It is possible to group the 122 species as follows:

Group 1. Not macropterous; no ventral abdominal fenestrae.

Campylacantha olivacea olivacea
Dichromorpha viridis
Hypochlora alba
Kosciuscola tristis
Melanoplus flabellatus
Melanoplus dawsoni
Melanoplus scudderi
Melanoplus walshii
Neopodismopsis abdominalis
Paratylotropidia brunneri
Phaulacridium vittatum
Phoetaliotes nebrascensis
Romalea microptera

Total 13 species

Group 2. Not macropterous; ventral abdominal fenestrae present.

Brachystola magna
Hesperotettix speciosus
Paraidemona punctata
Pyrgomorphella arachidis — Total 4 species

Group 3. Macropterous; ventral abdominal fenestrae present.

Catantops curvicercus
Cyrtacanthacris tatarica tatarica
Locheuma brunneri
Phymateus pulcherrimus
Pyrgomorpha sp.
Pyrgomorpha sp.
Saussurea stuhlmanniana
Tanita sp. — Total 8 species

Group 4. Macropterous; no ventral abdominal fenestrae.

All other species examined — Total 97 species

The χ^2 test was applied to the figures for the four groups and the probability that the association of ventral abdominal fenestrae with the apterous or brachypterous condition was due to chance alone was calculated. When this was done, using Yates' correction, χ^2 was found to be 2.56 and, with one degree of freedom, P is just above 0.11. The result is an indecisive one and it is not possible to state with any confidence either that there is or is not a significant association between wing development and ventral abdominal fenestrae. It would be interesting to obtain data for other apterous and brachypterous forms and to discover whether this possible relationship is upheld or disproven.

In certain brachypterous species of Acrididae occasional macropterous individuals are found. *Phoetaliotes nebrascensis* is one of these and the writer was fortunate in securing a long-winged laboratory-bred male which could be compared with the common short-winged form. An examination of the histograms for the two (figs. 119, 120) will show them to be very similar. The writer is not sufficiently acquainted with all of the brachypterous species studied to be certain in which ones long-winged forms also are known. Other North American species, included in group 1,

in which occasional macropterous individuals are found are *Dichromorpha viridis, Neopodismopsis abdominalis, Paratylotropidia brunneri* and *Melanoplus dawsoni.* The meagre evidence available suggests a question. Do those species in which only apterous or brachypterous forms occur tend to develop ventral abdominal fenestrae while those in which both short and long-winged forms are found fail to develop them? It is conceivable that ground-dwelling individuals which are unable to fly might derive special benefit from ventral heat-sensitive areas. Again, perhaps short-winged species which spend much of their time off the ground and in vegetation may have less need of such structures on the underside of the abdomen.

Spot Pattern and Body Size.—While the dissections were being made for this study it was difficult to avoid the impression that members of the subfamily Acridinae had, on the whole, a body-wall which was thinner and more delicate than had similar-sized members of the other subfamilies. Actual measurements were not made [5] but if it could be shown that the species which belong to this subfamily do have a relatively thin body wall, this condition might well be associated with the smaller number of heat-sensitive areas in the group and the smaller percentage of the total surface given over to them. It was suggested earlier (Slifer, 1951) that the increase in number of sensitive spots in *Locusta migratoria migratorioides* in successive nymphal stages might be correlated with an increase in the thickness of the cuticle as the individual becomes larger. A mature adult with its heavy body-wall might have more need of specialized thin areas through which radiation would pass quickly than would a newly hatched nymph with its much thinner cuticle.

One approach to the problem just outlined would be to search for possible correlations between body size and the spot pattern in all of the species studied. This has been done by sorting the data in tables 1 to 4 into four groups on the basis of (1) *total body surface area,* (which provides a convenient index of body size) and

[5] If an attempt is made to do this it would be important that comparisons of body-wall thickness be made only on adults in which the cuticle has been completely formed and not on teneral individuals. It is known that in some species the secretion of the cuticle continues for several days after the final molt.

(2) the number of pairs of heat-sensitive spots found for each and applying the χ^2 test to the results. The data for two individuals, both *Melanoplus differentialis differentialis,* were discarded since it seemed better not to include more than one individual of the same species and from the same environment. Two, or at most three, individuals of each of several other species (*Cyrtacanthacris tatarica tatarica, Locusta migratoria migratorioides, Locustana pardalina, Oedaleus senegalensis, Phoetaliotes nebrascensis* and *Schistocerca gregaria*) have been included since these were collected in widely separated geographic regions or else represent dimorphic or phase forms. The mean total body surface area for all of the species of Acrididae considered was 447 mm^2 and the mean number of heat-sensitive spots was 10 pairs. *Group 1* included eleven species with body surface area over 447 mm^2 and a spot number of 10 or below; *group 2* included thirty-seven species with both surface area and spot number above the average; *group 3* was composed of sixty species with both surface area and spot number average or below and *group 4* contained twenty-eight species with a surface area below 447 mm^2 and with more than 10 pairs of spots. The numbers for the four groups were arranged in a 2 x 2 table and χ^2 calculated. χ^2 was found to be 18.6 and the probability that such a distribution is due to chance alone is less than 0.00002. A highly significant association between the size of the individual and the number of heat-sensitive areas on it thus exists. Large species, in general, have large numbers of spots and small species have fewer of them. It may be of some interest to note, in this connection, that Pepper and Hastings (1952), who studied the rise in body temperature of three species of grasshoppers (*Melanoplus bivittatus, Melanoplus differentialis* and *Melanoplus mexicanus*) when exposed to solar radiation, have reported that the average rise for *Melanoplus bivittatus* and *Melanoplus differentialis* was higher than that for *Melanoplus mexicanus.* The first two species are large insects and the third is small.

Spot Pattern and the Number of Individuals of a Species.—The positions within the lists given in tables 1 to 4 of the more successful species, as indicated by their abundance, is a matter of considerable interest. Data for the major plague species have been

brought together in table 5 and it is obvious at a glance that all of them are very well provided with these special heat-sensitive areas. The number of pairs of spots is large (11 to 14 pairs), they range in size from moderate to large (0.34 to 1.30% of the total body surface) and they are widely scattered over the body (11 to 13 body parts). All of these will be found in group 2 on page 53. No consistent differences between individuals of the solitary and the gregarious phase are apparent but many individuals of each phase should be examined before any conclusion is drawn. In table 6 data for North American grasshoppers which frequently become so numerous as to be agricultural pests have been brought together. Here, again, each species is well provided with the special areas. With two exceptions (*Melanoplus femur-rubrum femur-rubrum* and *Melanoplus keeleri luridus*) all of them fall into groups 2 and 4 on page 53 and *Melanoplus femur-rubrum femur-rubrum* is the only species with a spot number which falls below the mean for the family. The patterns for highly successful, economically important species, thus, have much in common and it is difficult to believe that the possession of a well-developed pattern of heat-sensitive spots is not a definite asset for these insects. Conversely, we might expect that those species with few or with poorly distributed spots would be to some extent handicapped. The total picture would, of course, be complicated by many other factors. Even when a favorable pattern is present the insect may be hindered by some deficiency of a completely different and, as yet, unknown kind. *Paratylotropidia brunneri,* to take one example, is a relatively rare species although its spot pattern seems to be a favorable one. On the other hand in those species where the spot pattern is poorly developed the individuals may be able to compensate for it by reacting in another way to radiation or by occupying a habitat where great sensitivity to radiation is not important. The impression in the writer's mind, at present, is that in developing these varied and often complex patterns of heat-sensitive areas the more successful Acrididae have evolved a system whereby they will be able to utilize an external source of heat to their own maximum possible benefit and when this point is reached and the danger point approached they will be equally quick to turn away from it.

Summary

1. Specialized, heat-sensitive areas have been found on the body surface of all except one of the males of 122 species of Acrididae which were collected in many parts of the world and which represent six subfamilies.

2. The sensitive areas vary widely in number, size, shape and in their distribution pattern on the body in the different species studied.

3. In 93% of the males studied the heat-sensitive areas on the fourth, fifth and sixth abdominal terga were the largest on the entire body. These fenestrae, presumably, serve to protect the spermatozoa from excessive heat for the reproductive organs are located just below them.

4. A number of the brachypterous species which were studied are provided with ventral abdominal fenestrae but a χ^2 test of the data for a possible correlation between the presence of these areas and the extent of wing development gave inconclusive results.

5. A highly significant correlation was found between body size and the number of heat-sensitive spots. Large species tend to have a larger number of the areas than do small species. The former, with their heavier body walls, probably have more need of these specialized thin areas through which heat can be quickly detected.

6. Those species of locusts and grasshoppers which occur in such abundance as to be serious agricultural pests were all found to be well furnished with these specialized areas.

Table 1

Heat-sensitive areas of one species of Pamphaginae and of seven species of Pyrgomorphinae. Species of latter subfamily arranged in order according to number of pairs of special areas, number of body-parts which bear them and percentage of the total body surface occupied by them. All individuals are males.

Species	No. of pairs of spots	No. of body parts with spots	% total surface occupied by spots	Total body surface ($mm.^2$)
Saussurea stuhlmanniana	14	9	0.91	1048
Pyrgomorphella arachidis	8	8	0.52	286
Chrotogonus sp.	11	11	0.32	176
Pyrgomorpha sp.	11	11	0.35	130
Pyrgomorpha sp.	12	11	0.31	151
Pyrgomorpha sp.	13	11	0.36	137
Tanita sp.	17	11	0.70	380
Phymateus pulcherrimus	19	12	0.98	1397

Table 2

Heat-sensitive areas of males of twenty species and subspecies of Acridinae. Species arranged in order according to number of pairs of these special areas, number of body parts which bear them and percentage of the total body surface occupied by them.

Species	No. of pairs of spots	No. of body parts with spots	% total surface occupied by spots	Total body surface ($mm.^2$)
Ageneotettix deorum	4	4	0.18	175
Syrbula admirabilis	5	5	0.24	313
Neopodismopsis abdominalis	6	6	0.39	206
Chorthippus longicornis	6	6	0.40	165
Mermiria maculipennis macclungi	6	6	0.35	259
Acrida sp.	7	7	0.19	373
Acrida bicolor	7	7	0.30	423
Eritettix s. simplex	7	7	0.48	163
Boopedon nubilum	7	7	0.53	546
Acrida sp.	8	8	0.12	478
Amphitornus c. coloradus	8	8	0.36	219
Orphulella speciosa	8	8	0.35	179
Metalepta brevicornis int. b.b. and b. adspersa	8	8	0.50	302

Table 2 (cont.)

Species	No. of pairs of spots	No. of body parts with spots	% total surface occupied by spots	Total body surface ($mm.^2$)
Dichromorpha viridis	8	8	0.57	165
Metalepta brevicornis adspersa	9	9	0.50	210
Orphulella sp.	9	9	0.49	126
Mermiria m. maculipennis	9	9	0.66	625
Duronia tricolor	10	10	0.47	311
Boopedon maculatum	10	10	0.66	578
Caledia captiva	11	11	0.84	269

Table 3

Heat-sensitive areas of males of fifty species, subspecies and phase forms of Oedipodinae. Species arranged in order according to number of pairs of these special areas, number of body parts which bear them and % of the total body surface occupied by them.

Species	No. of pairs of spots	No. of body parts with spots	% total surface occupied by spots	Total body surface ($mm.^2$)
Acrotylus longipes	5	5	0.24	197
Austroicetes pusilla	8	8	0.27	104
Sphingonotus savignyi	8	8	0.34	432
Morphacris fasciata	8	8	0.35	241
Oedaleus senegalensis	8	8	0.57	377
Spharagemon collare	8	8	0.60	288
Aiolopus savignyi	8	8	0.60	241
Gastrimargus musicus	8	8	0.66	578
Trachyrhachis kiowa fuscifrons	9	9	0.31	188
Acrotylus sp.	9	9	0.36	168
Acrotylus patruelis	9	9	0.42	197
Oedaleus citrinus	9	9	0.53	322
Chortophaga viridifasciata	9	9	0.57	357
Encoptolophus s. sordidus	9	9	0.63	320
Gastrimargus africanus	9	9	0.77	636
Morphacris fasciata	9	9	0.78	231
Acrotylus variegatus	10	10	0.24	195
Encoptolophus sordidus costalis	10	10	0.44	279
Psinidia f. fenestralis	10	10	0.45	195
Aiolopus sp.	10	10	0.55	165
Derotmema haydenii laticinctum	10	10	0.57	195
Tmetonota peregrina	10	10	0.57	200

Table 3 (cont.)

Species	No. of pairs of spots	No. of body parts with spots	% total surface occupied by spots	Total body surface ($mm.^2$)
Oedaleus australis	10	10	0.61	284
Aiolopus sp.	10	10	0.66	231
Trimerotropis m. maritima	10	10	0.72	329
Spharagemon bolli	10	10	0.75	320
Arphia pseudonietana	10	10	0.81	389
Arphia sulphurea	10	10	0.84	400
Hippiscus rugosus	10	10	0.85	483
Encoptolophus s. subgracilis	10	10	0.89	173
Heliastus venezuelae	10	10	1.19	276
Locustana pardalina (phase solitaria)	11	11	0.34	747
Trilophidia sp.	11	11	0.51	192
Aiolopus sp.	11	11	0.56	241
Spharagemon equale	11	11	0.58	685
Hadrotettix trifasciatus	11	11	0.60	672
Locustana pardalina (phase gregaria)	11	11	0.61	1010
Rehnita gracilipes	11	11	0.68	207
Pycnodictya miniatiapennis	11	11	0.68	414
Oedaleus senegalensis	11	11	0.70	364
Pardalophora apiculata	11	11	0.86	578
Humbe tenuicornis	11	11	1.10	351
Locusta migratoria migratorioides (phase gregaria)	11	11	1.14	1018
Locusta migratoria migratorioides (phase solitaria)	11	11	1.30	759
Dissosteira carolina	12	11	0.68	586
Conozoa s. sulcifrons	12	12	0.59	263
Locusta migratoria migratorioides (phase solitaria)	12	12	1.12	985
Camnula pellucida	12	12	1.13	280
Arphia xanthoptera	14	11	1.10	766
Trimerotropis p. pallidipennis	14	12	0.77	371

TABLE 4

Heat-sensitive areas of males of fifty-three species, subspecies and dimorphic and phase forms of Cyrtacanthacridinae. Species arranged in order according to numbers of pairs of these special areas, number of body-parts which bear them and % of the total body surface occupied by them.

Species	No. of pairs of spots	No. of body parts with spots	% total surface occupied by spots	Total body surface (mm.²)
Kosciuscola tristis	0	0	0	246
Hypochlora alba	4	4	0.23	201
Macrotona australis	6	6	0.23	215
Schistocerca alutacea	7	7	0.49	658
Tetrataenia surinama	7	7	0.95	251
Cataloipus sp.	8	8	0.92	653
Phoetaliotes nebrascensis (short)	9	9	0.35	251
Phoetaliotes nebrascensis (long)	9	9	0.42	261
Thisoicetrus annulosus	9	9	0.68	280
Melanoplus f.-r. femur-rubrum	9	9	0.73	340
Melanoplus flabellatus	9	9	0.77	296
Paraidemona punctata	10	9	0.82	302
Schistocerca lineata	10	10	0.45	846
Peakesia fuscomaculata	10	10	0.57	274
Melanoplus d. differentialis	10	10	0.75	573
Melanoplus walshii	10	10	0.77	328
Melanoplus s. scudderi	10	10	0.83	241
Melanoplus dawsoni	10	10	0.85	193
Melanoplus keeleri luridus	10	10	0.89	260
Melanoplus glaucipes	10	10	0.92	429
Paratylotropidia brunneri	10	10	1.24	457
Hesperotettix speciosus	11	10	0.93	487
Caloptenopsis meruensis	11	10	0.98	351
Phaulacridium nanum	11	11	0.34	83
Hesperotettix v. viridis	11	11	0.66	285
Melanoplus infantilis	11	11	0.70	168
Melanoplus m. mexicanus	11	11	0.71	338
Melanoplus p. ponderosus	11	11	0.74	779
Melanoplus d. differentialis	11	11	0.77	592
Melanoplus d. differentialis	11	11	0.88	692
Campylacantha o. olivacea	11	11	0.89	226
Melanoplus angustipennis	11	11	0.93	291
Melanoplus foedus fluviatilis	11	11	1.00	270
Schistocerca americana	11	11	1.00	979
Melanoplus differentialis nigricans	11	11	1.09	946

Table 4 (cont.)

Species	No. of pairs of spots	No. of body parts with spots	% total surface occupied by spots	Total body surface ($mm.^2$)
Melanoplus bivittatus	11	11	1.21	764
Locheuma brunneri	12	10	0.90	256
Phaulacridium vittatum	12	12	0.58	166
Schistocerca gregaria (phase solitaria)	12	12	0.69	1285
Melanoplus bispinosus	12	12	0.69	490
Schistocerca gregaria (phase gregaria)	12	12	0.81	1219
Melanoplus f. flavidus	12	12	0.94	614
Schistocerca sp.	12	12	0.99	858
Osmilia sp.	12	12	1.20	404
Melanoplus packardii	12	12	1.10	539
Cyrtacanthacris t. abyssinica	12	12	1.39	644
Cyrtacanthacris t. tatarica	13	11	1.12	1151
Romalea microptera	13	12	1.59	1422
Catantops axillaris	14	12	0.78	645
Cyrtacanthacris t. tatarica	14	12	1.12	1240
Nomadacris septemfasciata	14	13	1.00	1376
Brachystola magna	15	9	1.50	2213
Catantops sp.	15	13	0.80	271
Catantops curvicercus	16 *	12	1.77	130

Table 5

The heat-sensitive areas of the males of some of the major plague species of locusts of the world.

Species	No. of pairs of spots	No. of body parts with spots	% total surface occupied by spots	Total body surface ($mm.^2$)
Locustana pardalina (phase solitaria)	11	11	0.34	747
Locustana pardalina (phase gregaria)	11	11	0.64	1010
Locusta migratoria migratorioides (phase solitaria)	11	11	1.30	759
Locusta migratoria migratorioides (phase gregaria)	11	11	1.14	1018

* More exactly, 14 pairs plus two, single median spots.

Table 5 (cont.)

Species	No. of pairs of spots	No. of body parts with spots	% total surface occupied by spots	Total body surface (mm.^{2})
Schistocerca gregaria (phase solitaria)	12	12	0.69	1219
Locusta migratoria migratorioides (phase solitaria)	12	12	1.12	985
Schistocerca gregaria (phase gregaria)	12	12	0.81	1285
Nomadacris septemfasciata	14	13	1.00	1376

Table 6

The heat-sensitive areas of males of North American grasshoppers which are of importance as agricultural pests.

Species	No. of pairs of spots	No. of body parts with spots	% total surface occupied by spots	Total body surface (mm.^{2})
Melanoplus f.-r. femur-rubrum	9	9	0.73	340
Melanoplus d. differentialis	10	10	0.89	692
Melanoplus keeleri luridus	10	10	0.89	260
Melanoplus m. mexicanus	11	11	0.71	338
Melanoplus differentialis nigricans	11	11	1.09	946
Melanoplus bivittatus	11	11	1.21	764
Melanoplus packardii	12	12	1.10	539
Camnula pellucida	12	12	1.13	280

Explanation of Plates

Histograms showing pattern of heat-sensitive areas for various male Acrididae. Zero base-line of each divided into thirteen equal spaces. Each space represents a body-part, H, head; P, prothorax; MS, mesothorax; MT, metathorax; 1 to 9, abdominal segments one to nine. Rectangles extending vertically above zero base-line represent dorsal and dorso-lateral heat-sensitive areas and those extending below it represent ventral heat-sensitive areas. Parallelograms which slant to right represent lateral heat-sensitive areas which are located near abdominal spiracles. Percentage of total heat-sensitive area which is present on each region of each body part indicated by height of rectangle or parallelogram.

Plate I

Subfamilies Pamphaginae and Pyrgomorphinae

Fig. 1. *Saussurea stuhlmanniana* (Karsch), Shinyanga, Tanganyika.
Fig. 2. *Chrotogonus* sp., Wachiro, Eritrea.
Fig. 3. *Phymateus pulcherrimus* Bolivar, Ghinda, Eritrea.
Fig. 4. *Pyrgomorpha* sp., Wachiro, Eritrea.
Fig. 5. *Pyrgomorpha* sp., Wachiro, Eritrea.
Fig. 6. *Pyrgomorpha* sp., Keren, Eritrea.
Fig. 7. *Pyrgomorphella arachidis* Dirsh, Shinyanga, Tanganyika.
Fig. 8. *Tanita* sp., Shinyanga, Tanganyika.

Plate II

Subfamily Acridinae

Fig. 9. *Acrida bicolor* (Thunberg), Cum Ceua, Eritrea.
Fig. 10. *Acrida* sp., Shinyanga, Tanganyika.
Fig. 11. *Acrida* sp., Canberra, A.C.T., Australia.
Fig. 12. *Ageneotettix deorum* (Scudder), Boulder, Colorado.
Fig. 13. *Aphitornus coloradus coloradus* (Thomas), Boulder, Colorado.
Fig. 14. *Boopedon maculatum* Caudell, Waxahachie, Texas.
Fig. 15. *Boopedon nubilum* (Say), Canadian Brakes, Dumas, Texas.
Fig. 16. *Caledia captiva* (Fabricius), Canberra, A.C.T., Australia.

Plate III

Subfamily Acridinae

Fig. 17. *Chorthippus longicornis* (Latreille), University Lodge, Boulder, Colorado.
Fig. 18. *Dichromorpha viridis* (Scudder), Iowa.
Fig. 19. *Duronia tricolor* (Karny), Sabarghuma Plain, Eritrea.
Fig. 20. *Eritettix simplex simplex* (Scudder), Iowa.
Fig. 21. *Mermiria maculipennis maculipennis* Bruner, source(?).
Fig. 22. *Mermiria maculipennis macclungi* Rehn, Iowa.
Fig. 23. *Metalepta brevicornis adspersa* Blanchard, Yurimaguas, Peru.
Fig. 24. *Metalepta brevicornis* intermediate between *b. brevicornis* and *b. adspersa*, Cristobal, Canal Zone.

Plate IV

Subfamily Acridinae

Fig. 25. *Neopodismopsis abdominalis* (Thomas), University Lodge, Boulder, Colorado.
Fig. 26. *Orphulella speciosa* (Scudder), Iowa.
Fig. 27. *Orphulella* sp., Yurimaguas, Peru.
Fig. 28. *Syrbula admirabilis* (Uhler), Iowa.

Plate V

Subfamily Oedipodinae

Fig. 29. *Acrotylus longipes* (Charpentier), Wachiro, Eritrea.
Fig. 30. *Acrotylus patruelis* Herrich-Schäffer, Shinyanga, Tanganyika.
Fig. 31. *Acrotylus variegatus* Brancsik, Keren, Eritrea.
Fig. 32. *Acrotylus* sp., Asmara, Eritrea.
Fig. 33. *Aiolopus savignyi* (Krauss), Wachiro, Eritrea.
Fig. 34. *Aiolopus* sp., Asmara, Eritrea.
Fig. 35. *Aiolopus* sp., Sabarghuma Plain, Eritrea.
Fig. 36. *Aiolopus* sp., Shinyanga, Tanganyika.

Plate VI

Subfamily Oedipodinae

Fig. 37. *Arphia pseudonietana* (Thomas), Boulder, Colorado.
Fig. 38. *Arphia sulphurea* (Fabricius), Rochester, Iowa.
Fig. 39. *Arphia xanthoptera* (Burmeister), Wilmer, Texas. Pair of fenestrae on first sternal plate of prothorax indicated by a parallelogram which slants towards the left.
Fig. 40. *Austroicetes pusilla* (Walker), Canberra, A.C.T., Australia. Note absence of antennal crescents.
Fig. 41. *Camnula pellucida* (Scudder), Colorado.
Fig. 42. *Chortophaga viridifasciata* (DeGeer), Rochester, Iowa.
Fig. 43. *Conozoa sulcifrons sulcifrons* (Scudder), Phoenix, Arizona.
Fig. 44. *Derotmema haydenii laticinctum* Scudder, Phoenix, Arizona.

Plate VII

Subfamily Oedipodinae

Fig. 45. *Dissosteira carolina* (Linnaeus), Iowa.
Fig. 46. *Encoptolophus sordidus sordidus* (Burmeister), Iowa.
Fig. 47. *Encoptolophus sordidus costalis* (Scudder), source (?).
Fig. 48. *Encoptolophus subgracilis subgracilis* Caudell, Phoenix, Arizona.
Fig. 49. *Gastrimargus africanus* (Saussure), Shinyanga, Tanganyika.
Fig. 50. *Gastrimargus musicus* (Fabricius), Canberra, A.C.T., Australia.
Fig. 51. *Hadrotettix trifasciatus* (Say), source (?).
Fig. 52. *Heliastus venezuelae* Saussure, Cristobal, Canal Zone.

PLATE VIII

Subfamily Oedipodinae

Fig. 53. *Hippiscus rugosus* (Scudder), Iowa.
Fig. 54. *Humbe tenuicornis* (Schaum), Shinyanga, Tanganyika.
Fig. 55. *Locusta migratoria migratorioides* (Reiche and Fairmaire) phase solitaria, Wachiro, Eritrea.
Fig. 56. *Locusta migratoria migratorioides* (Reiche and Fairmaire) phase solitaria, Anti-Locust Research Centre, London. Laboratory-bred.
Fig. 57. *Locusta migratoria migratorioides* (Reiche and Fairmaire) phase gregaria, Anti-Locust Research Centre, London. Laboratory-bred.
Fig. 58. *Locustana pardalina* (Walker) phase solitaria, Pretoria, South Africa.
Fig. 59. *Locustana pardalina* (Walker) phase gregaria, Pretoria, South Africa.
Fig. 60. *Morphacris fasciata* (Thunberg), Shinyanga, Tanganyika.

PLATE IX

Subfamily Oedipodinae

Fig. 61. *Morphacris sanguinea* (Thunberg), Sabarghuma Plain, Eritrea.
Fig. 62. *Oedaleus australis* Saussure, Canberra, A.C.T., Australia.
Fig. 63. *Oedaleus citrinus* Saussure, Shinyanga, Tanganyika.
Fig. 64. *Oedaleus senegalensis* (Krauss), Shinyanga, Tanganyika.
Fig. 65. *Oedaleus senegalensis* (Krauss), Sabarghuma Plain, Eritrea.
Fig. 66. *Pardalophora apiculata* (Harris), Rochester, Iowa.
Fig. 67. *Psinidia fenestralis fenestralis* (Serville), Iowa.
Fig. 68. *Pycnodictya miniatiapennis* (Karsch), Shinyanga, Tanganyika.

PLATE X

Subfamily Oedipodinae

Fig. 69. *Rehnita gracilipes* (Caudell), Phoenix, Arizona.
Fig. 70. *Spharagemon bolli* Scudder, Iowa.
Fig. 71. *Spharagemon collare* (Scudder), Iowa.
Fig. 72. *Spharagemon equale* (Say), source (?).
Fig. 73. *Sphingonotus savignyi* Saussure, Wachiro, Eritrea.
Fig. 74. *Tmetonota peregrina* Karny, Shinyanga, Tanganyika.
Fig. 75. *Trachyrhachis kiowa fuscifrons* (Stål), Iowa.
Fig. 76. *Trilophidia* sp., Sabarghuma Plain, Eritrea.

PLATE XI

Subfamilies Oedipodinae, Romaleinae and Cyrtacanthacridinae

Fig. 77. *Trimerotropis maritima maritima* (Harris), Woods Hole, Massachusetts.
Fig. 78. *Trimerotropis pallidipennis pallidipennis* (Burmeister), Phoenix, Arizona.

Fig. 79. *Brachystola magna* (Girard), Wichita Falls, Texas. Fenestrae on first sternal plate of prothorax indicated by a parallelogram which slants towards the left.
Fig. 80. *Caloptenopsis meruensis* (Sjöstedt), Shinyanga, Tanganyika.
Fig. 81. *Campylacantha olivacea olivacea* (Scudder), Iowa.
Fig. 82. *Cataloipus* sp., Shinyanga, Tanganyika.
Fig. 83. *Catantops axillaris* (Thunberg), Jebel Halibai, Eritrea.
Fig. 84. *Catantops curvicercus* Miller, Shinyanga, Tanganyika.

PLATE XII

Subfamily Cyrtacanthacridinae

Fig. 85. *Catantops* sp., Shinyanga, Tanganyika.
Fig. 86. *Cyrtacanthacris tatarica tatarica* (Linnaeus), Shinyanga, Tanganyika.
Fig. 87. *Cyrtacanthacris tatarica tatarica* (Linnaeus), Wachiro, Eritrea.
Fig. 88. *Cyrtacanthacris tatarica abyssinica* Uvarov, Asmara, Eritrea. 7,600 feet.
Fig. 89. *Hesperotettix speciosus* (Scudder), source (?).
Fig. 90. *Hesperotettix viridis viridis* (Thomas), Texas.
Fig. 91. *Hypochlora alba* (Dodge), Boulder, Colorado.

PLATE XIII

Subfamily Cyrtacanthacridinae

Fig. 92. *Locheuma brunneri* (Scudder), Yurimaguas, Peru.
Fig. 93. *Macrotona australis* (Walker), Canberra, A.C.T., Australia.
Fig. 94. *Melanoplus angustipennis* (Dodge), Iowa.
Fig. 95. *Melanoplus bispinosus* Scudder, Texas.
Fig. 96. *Melanoplus bivittatus* (Say), Waxahachie, Texas.
Fig. 97. *Melanoplus dawsoni* (Scudder), Iowa.
Fig. 98. *Melanoplus differentialis differentialis* (Thomas), Iowa. Laboratory-bred.
Fig. 99. *Melanoplus differentialis nigricans* Cockerell, Waxahachie, Texas.

PLATE XIV

Subfamily Cyrtacanthacridinae

Fig. 100. *Melanoplus femur-rubrum femur-rubrum* (DeGeer), Waxahachie, Texas.
Fig. 101. *Melanoplus flabellatus* (Scudder), source (?).
Fig. 102. *Melanoplus flavidus flavidus* Scudder, Wilmer, Texas.
Fig. 103. *Melanoplus foedus fluviatilis* Bruner, Iowa.
Fig. 104. *Melanoplus glaucipes* (Scudder), Tehacuana Creek Bottoms, Waco, Texas.
Fig. 105. *Melanoplus infantilis* Scudder, University Lodge, Boulder, Colorado.
FIG. 106. *Melanoplus keeleri luridus* (Dodge), Iowa.
Fig. 107. *Melanoplus mexicanus mexicanus* (Saussure), Boulder, Colorado.

PLATE XV

Subfamily Cyrtacanthacridinae

Fig. 108. *Melanoplus packardii* Scudder, Canadian Brakes, Dumas, Texas.
Fig. 109. *Melanoplus ponderosus ponderosus* (Scudder), Waxahachie, Texas.
Fig. 110. *Melanoplus scudderi scudderi* (Uhler), Iowa.
Fig. 111. *Melanoplus walshii* Scudder, Iowa.
Fig. 112. *Nomadacris septemfasciata* (Serville), Shinyanga, Tanganyika.
Fig. 113. *Osmilia* sp., Yurimaguas, Peru.
Fig. 114. *Paraidemona punctata* (Stål), Tehacuana Creek Bottoms, Waco, Texas.
Fig. 115. *Paratylotropidia brunneri* Scudder, Iowa.

PLATE XVI

Subfamilies Romaleinae and Cyrtacanthacridinae

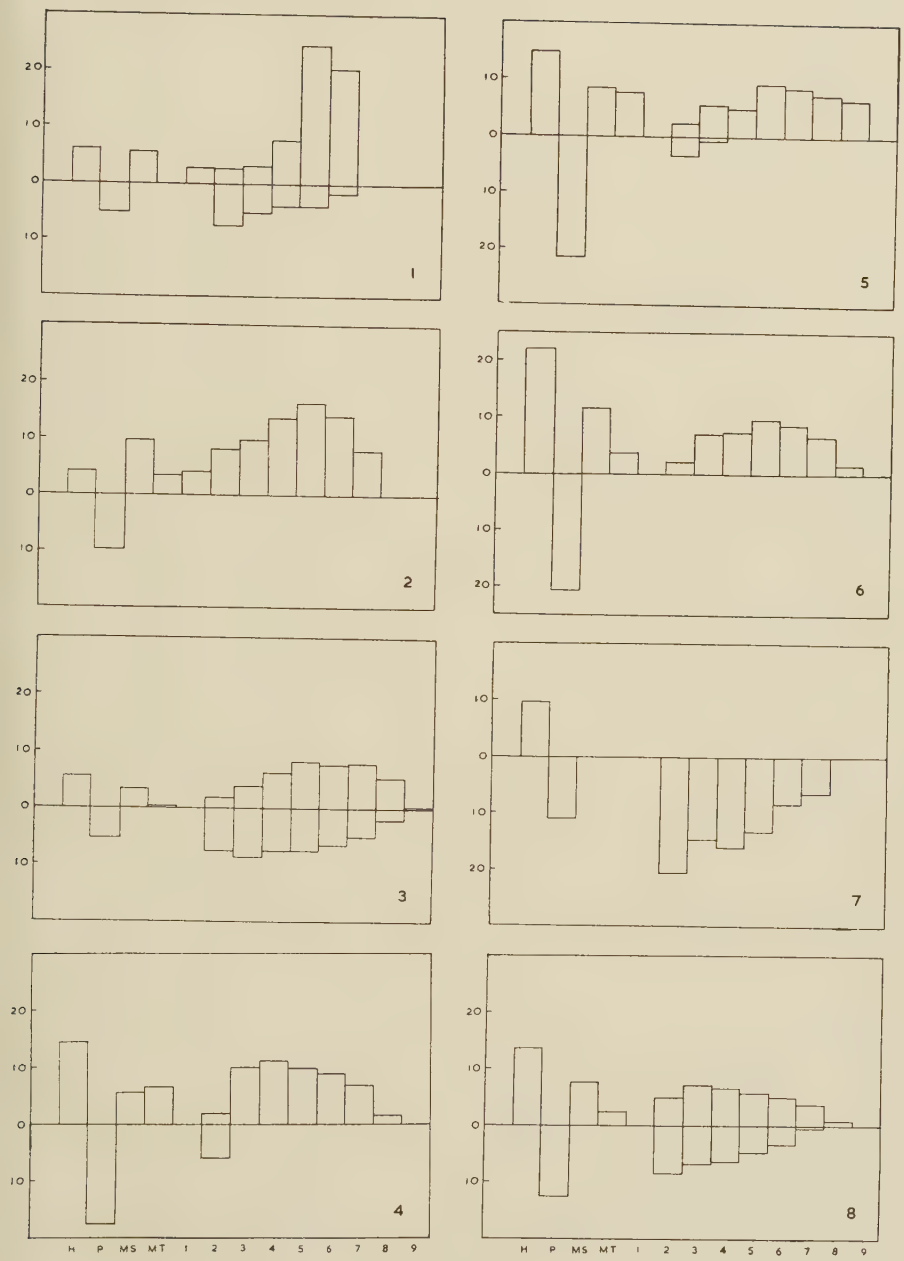
Fig. 116. *Peakesia fuscomaculata* Sjöstedt, Canberra, A.C.T., Australia.
Fig. 117. *Phaulacridium nanum* Sjöstedt, Canberra, A.C.T., Australia.
Fig. 118. *Phaulacridium vittatum* (Sjöstedt), Canberra, A.C.T., Australia.
Fig. 119. *Phoetaliotes nebrascensis* (Thomas), Iowa. Brachypterous.
Fig. 120. *Phoetaliotes nebrascensis* (Thomas), Iowa. Macropterous. Laboratory-bred.
Fig. 121. *Romalea microptera* (Beauvois), source (?).

PLATE XVII

Subfamily Cyrtacanthacridinae

Fig. 122. *Schistocerca alutacea* (Harris), Iowa.
Fig. 123. *Schistocerca americana americana* (Drury), Waxahachie, Texas.
Fig. 124. *Schistocerca gregaria* (Forskål), phase solitaria, Wachiro, Eritrea.
Fig. 125. *Schistocerca gregaria* (Forskål) phase gregaria, Anti-Locust Research Centre, London. Laboratory-bred.
Fig. 126. *Schistocerca lineata* Scudder, Wilmer, Texas.
Fig. 127. *Schistocerca* sp., Yurimaguas, Peru.
Fig. 128. *Tetrataenia surinama* (Linnaeus), Yurimaguas, Peru.
Fig. 129. *Thisoicetrus annulosus* (Walker), Wachiro, Eritrea.

Transactions of the American Entomological Society, Vol. LXXIX.
Pages 37–68 Issued October 21, 1953 1201.120



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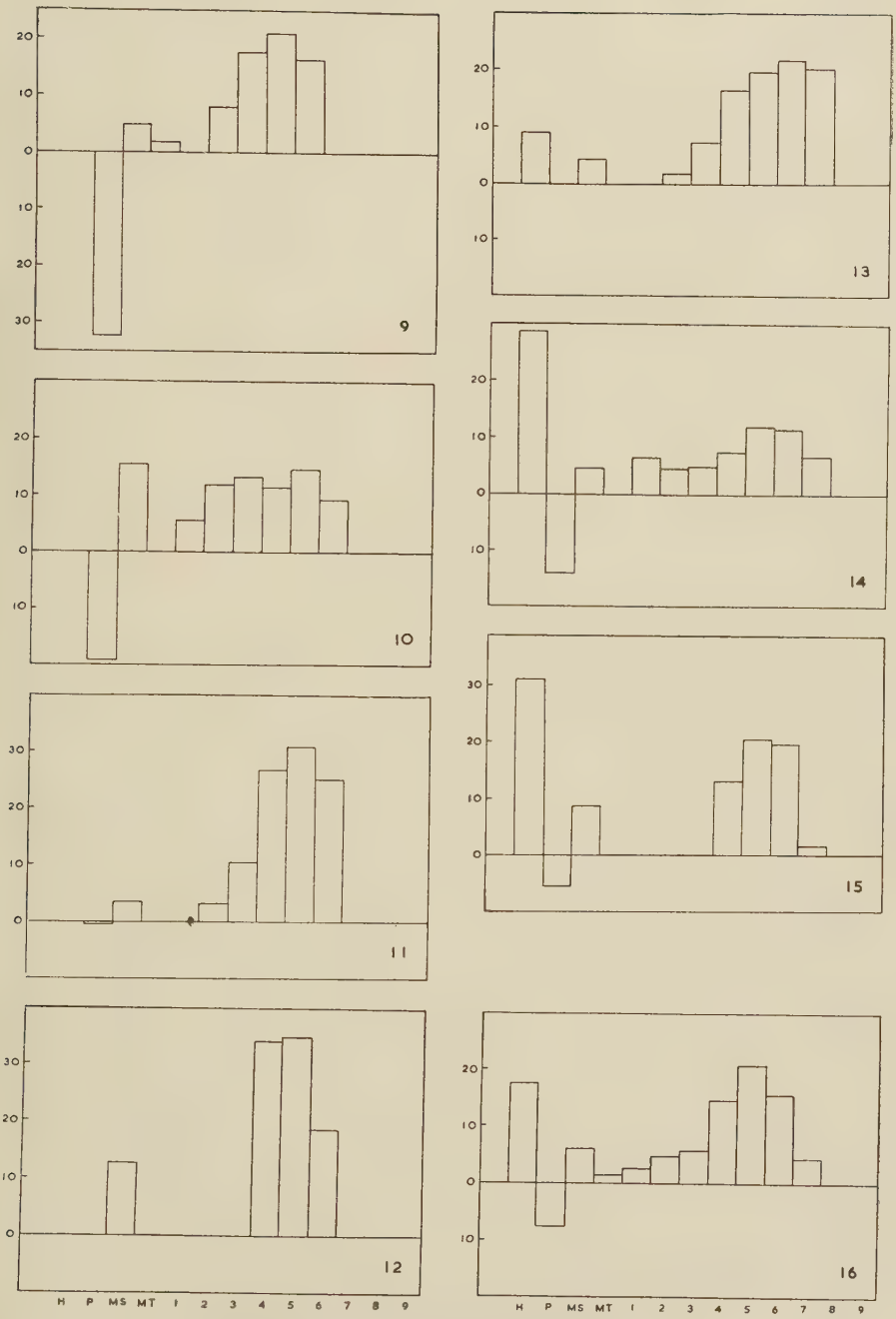

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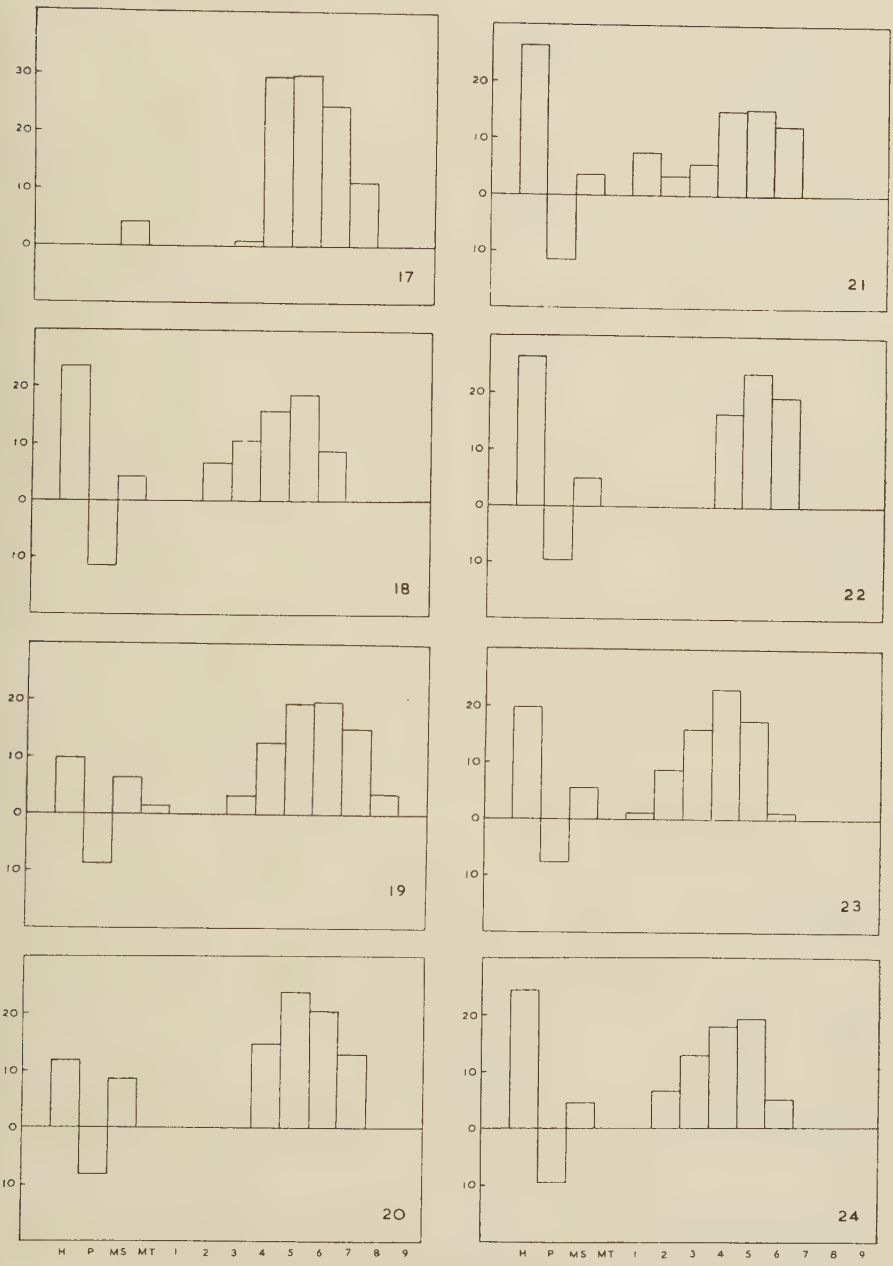

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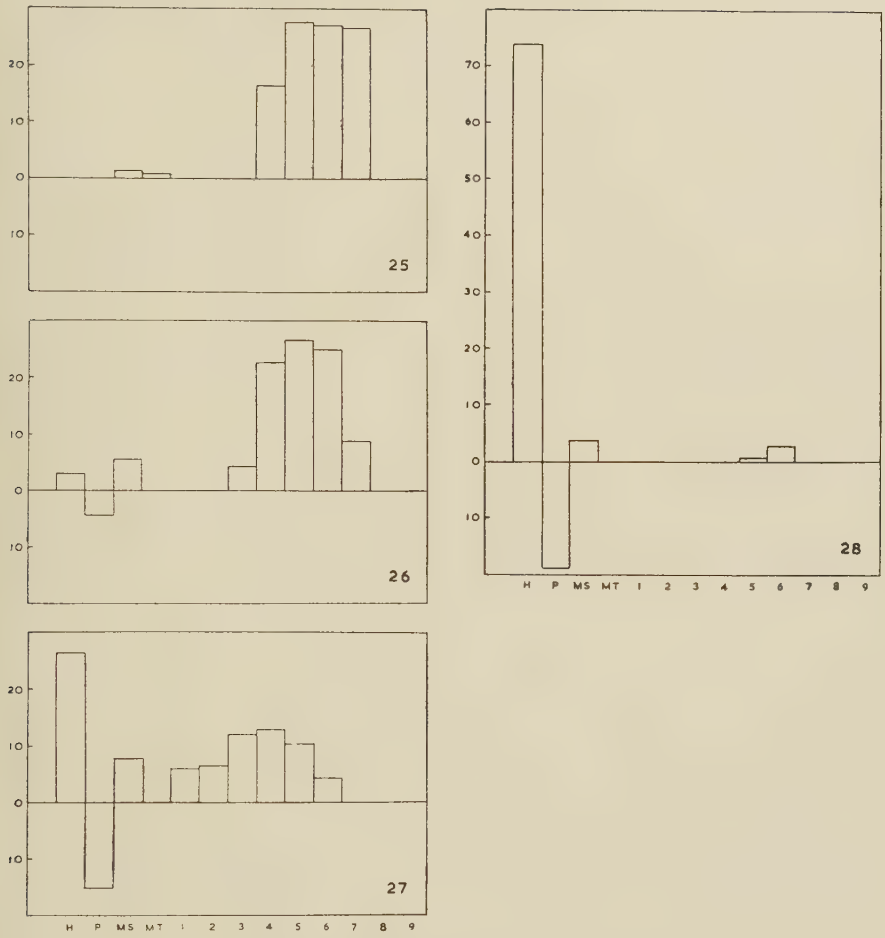

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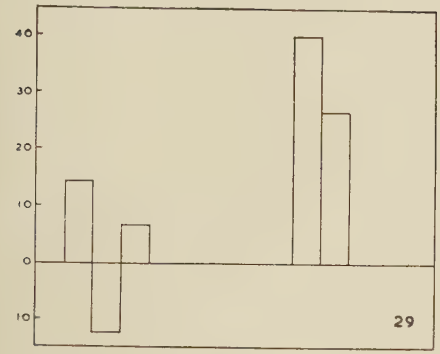

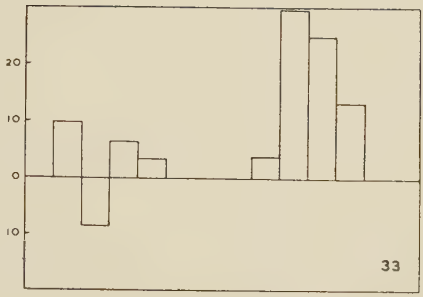

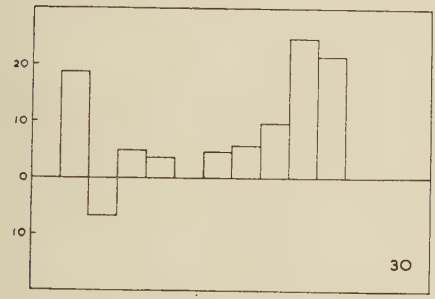

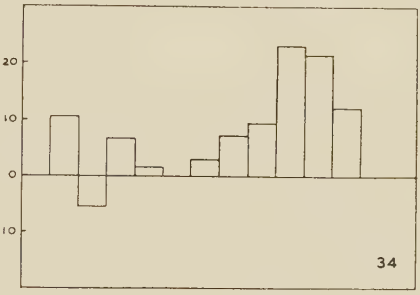

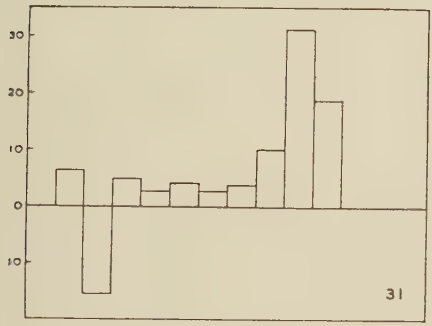

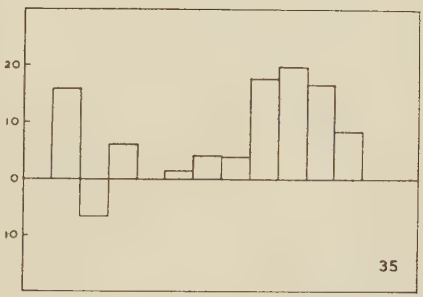

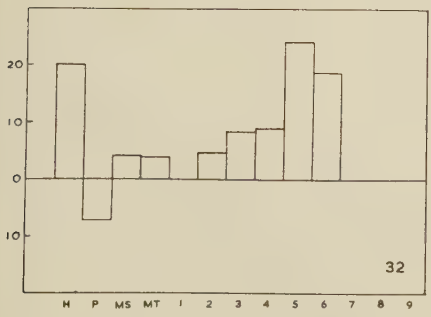

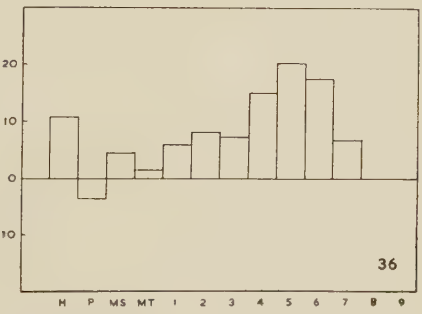

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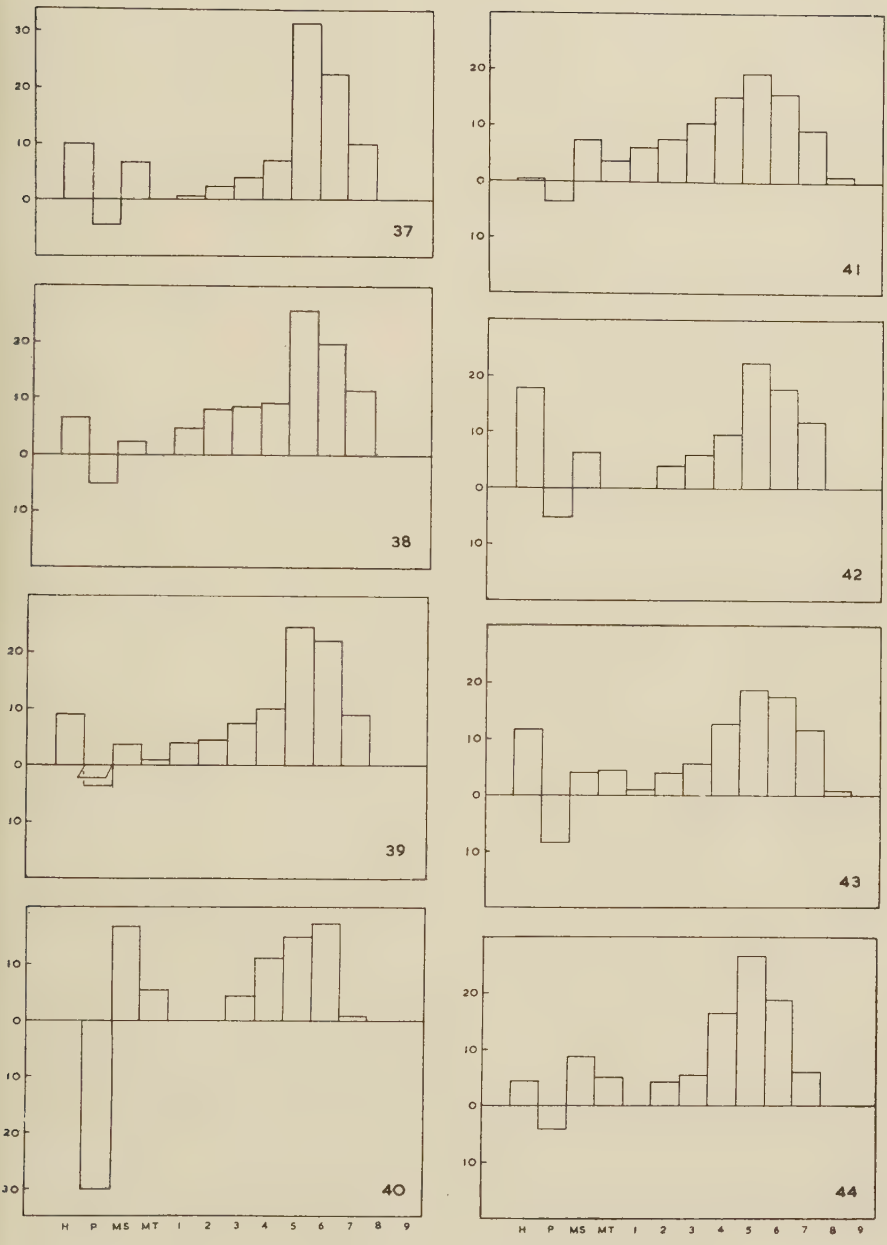

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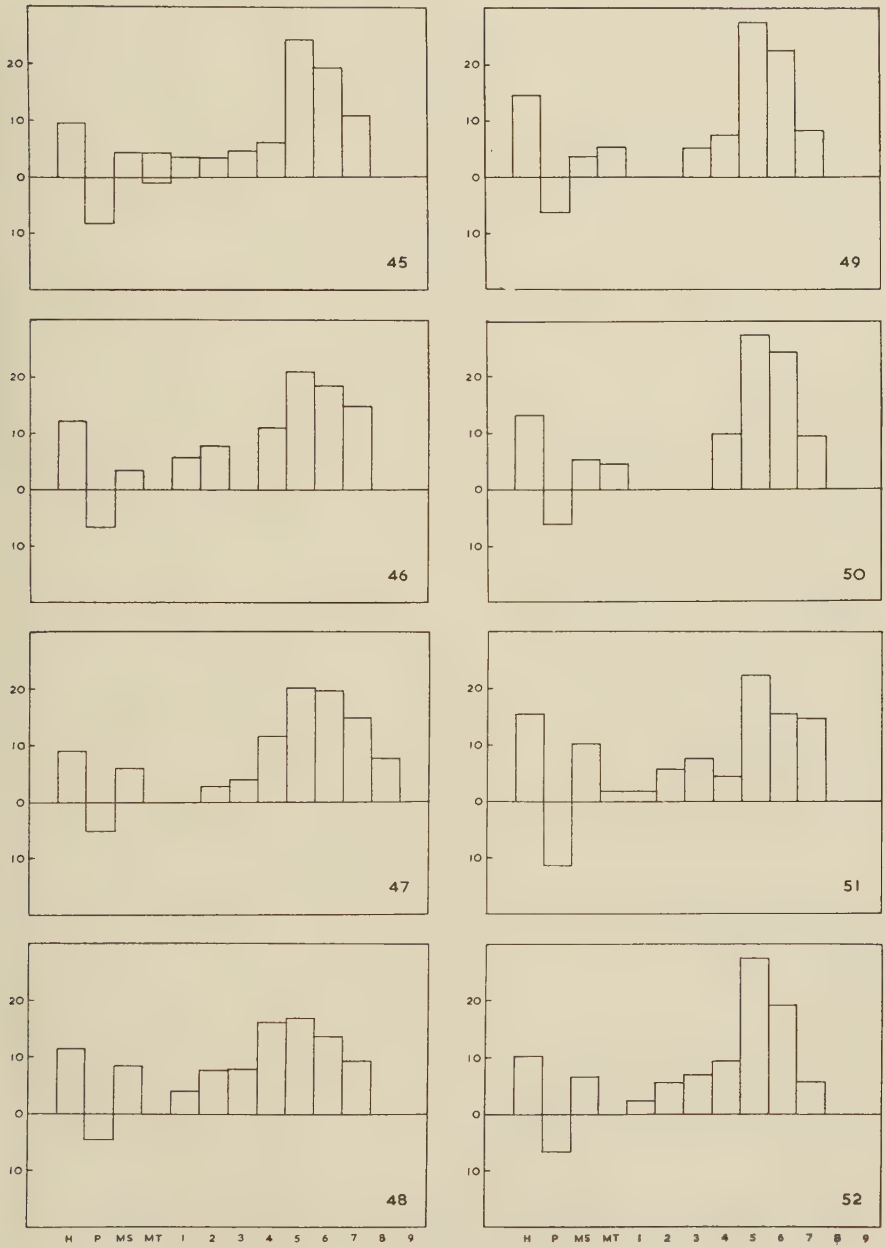

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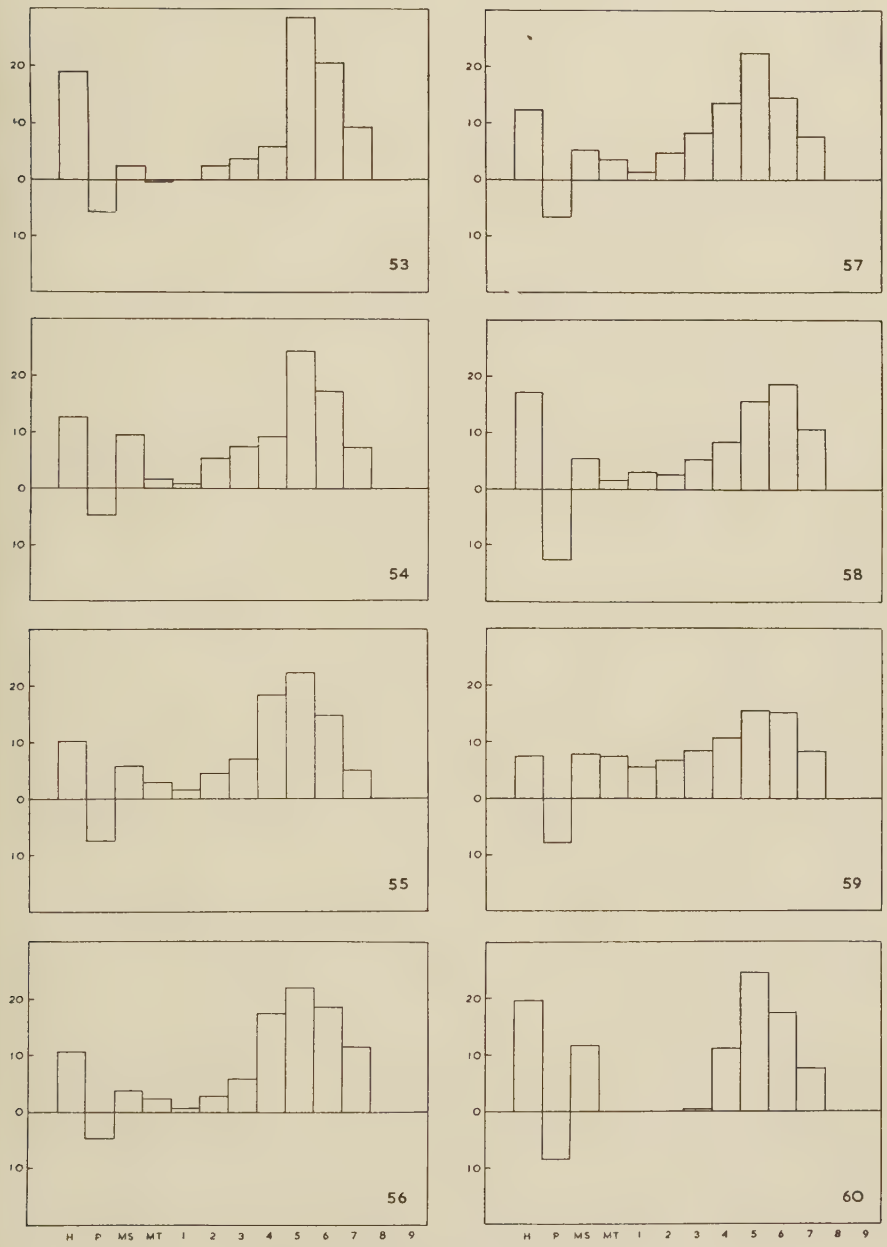

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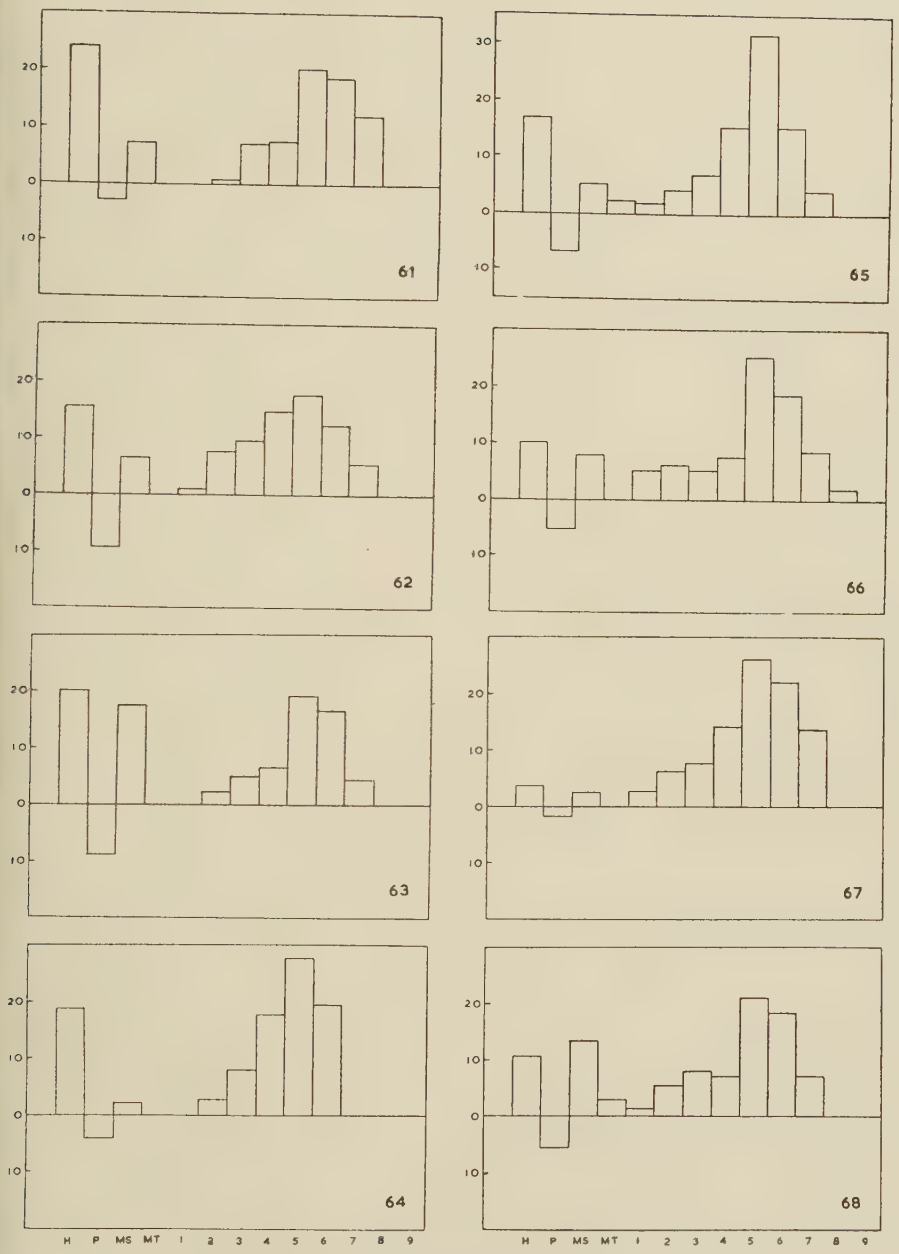

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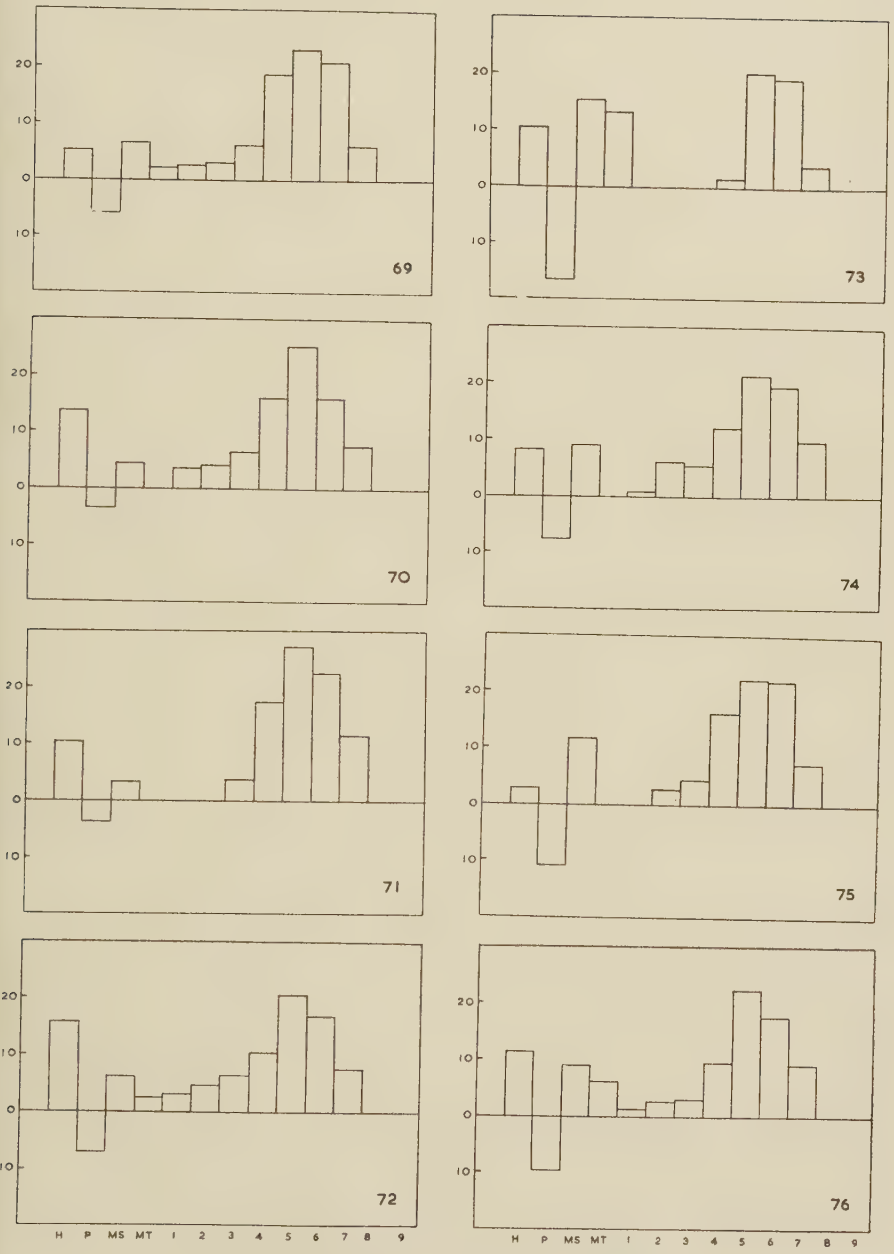

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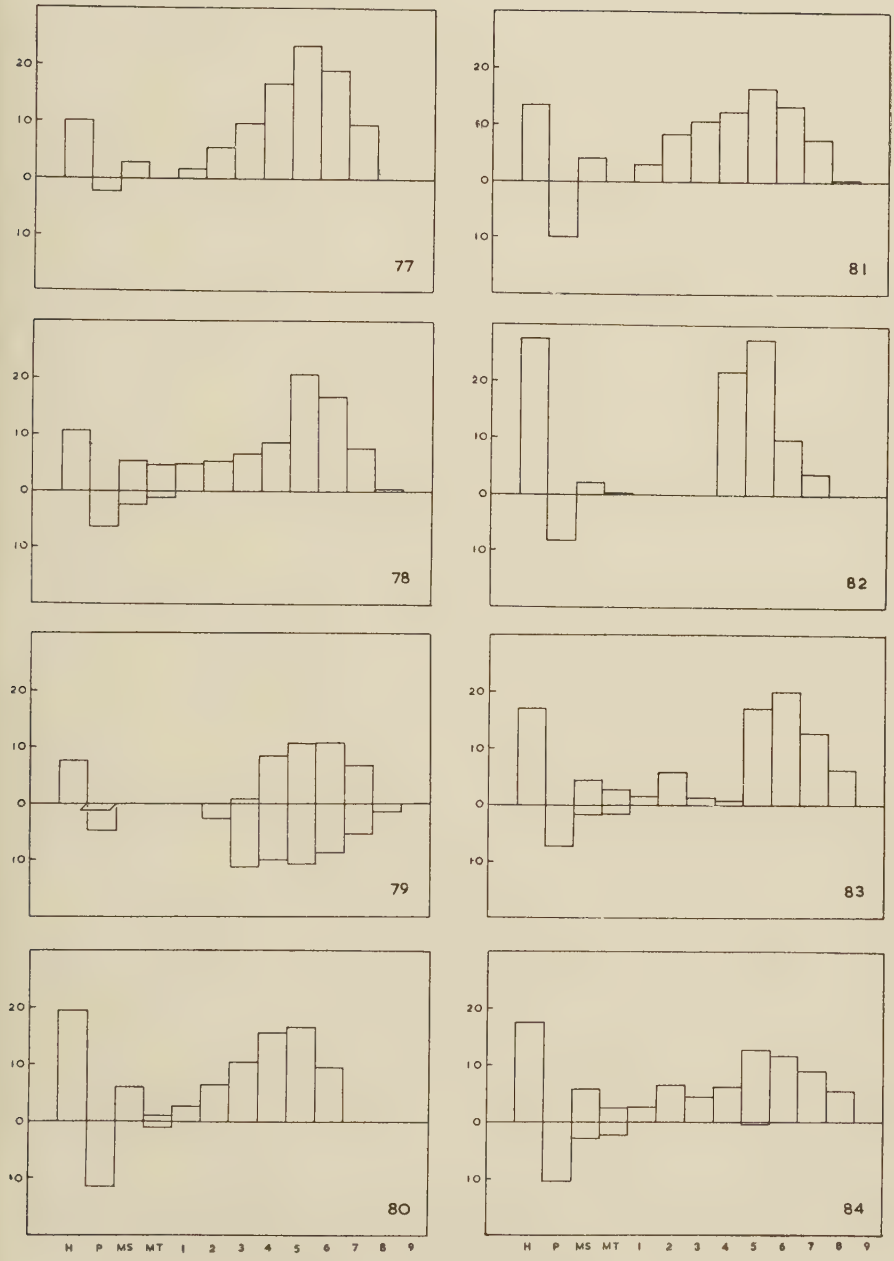

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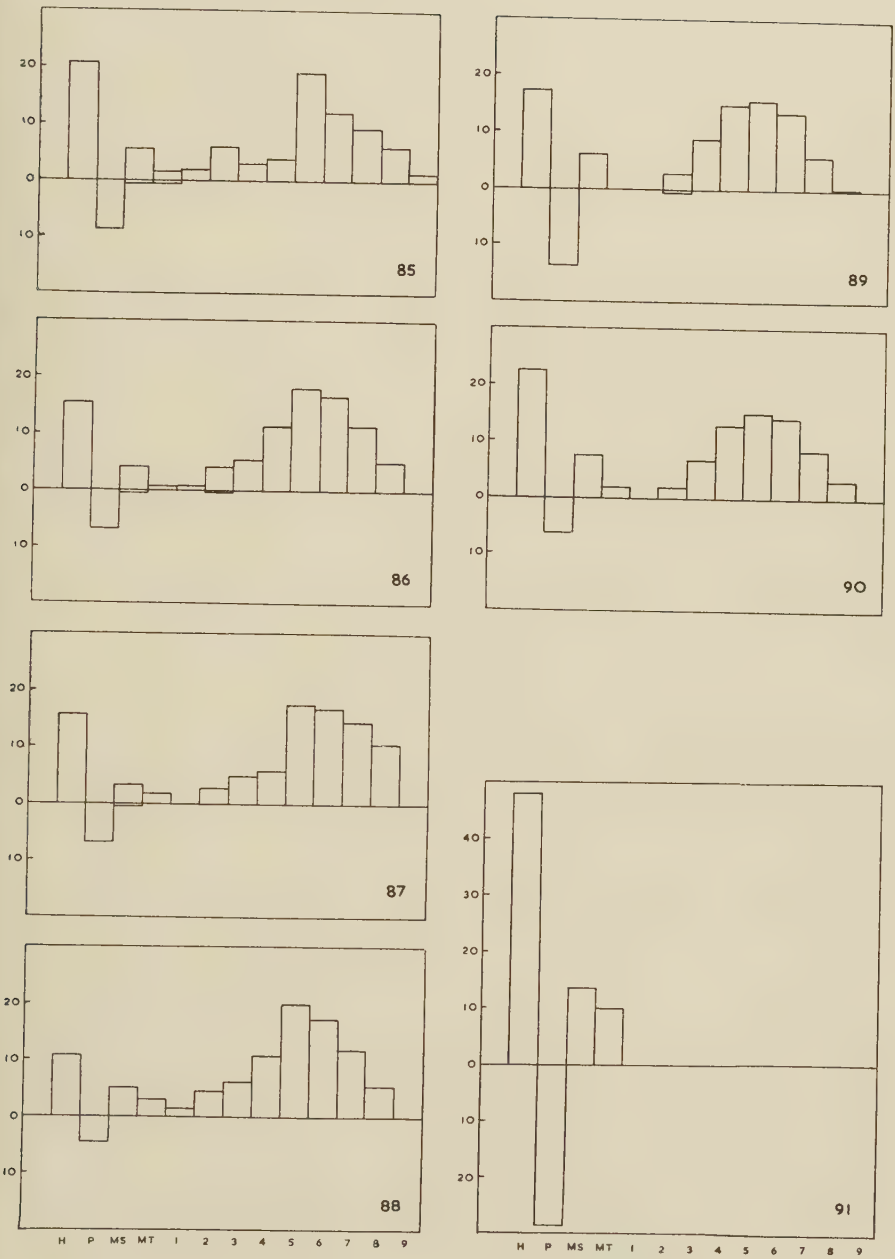

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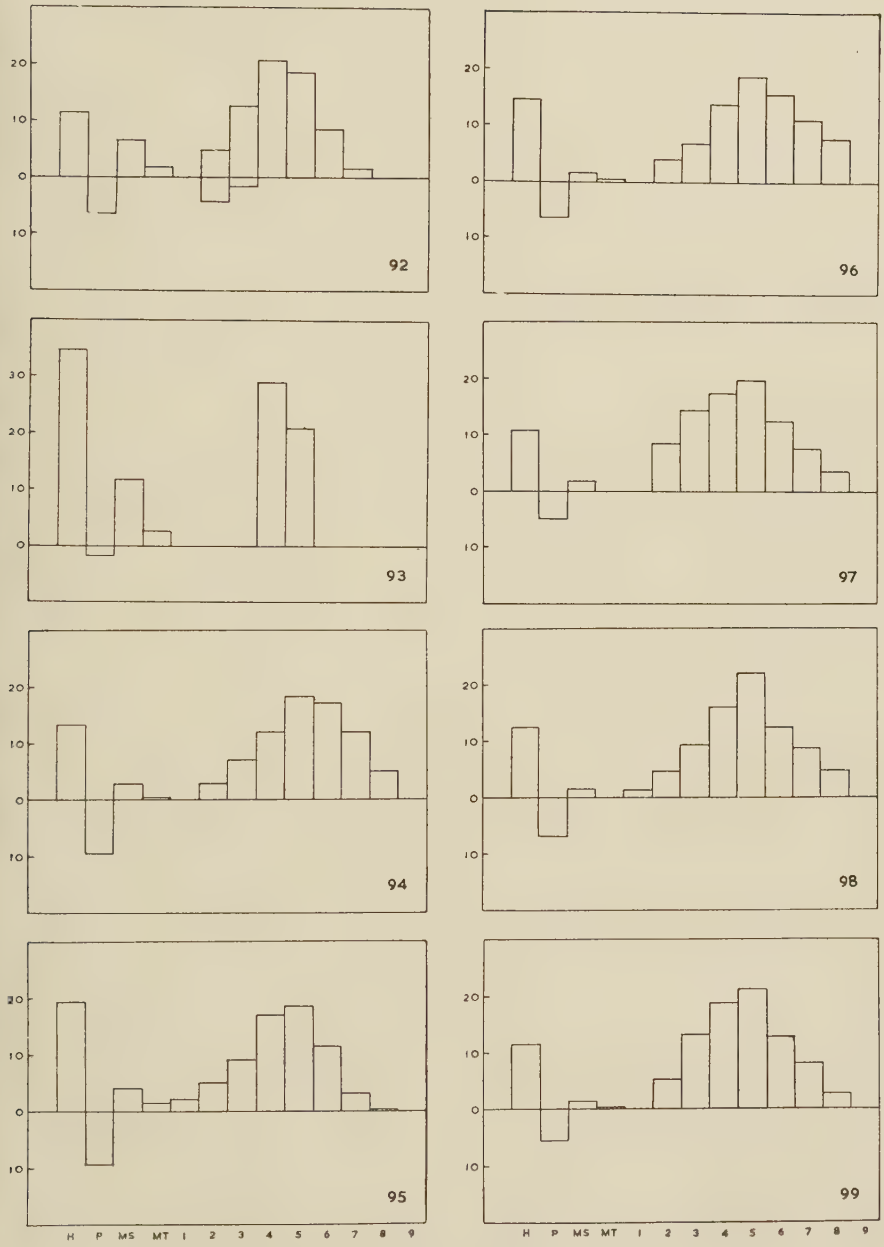

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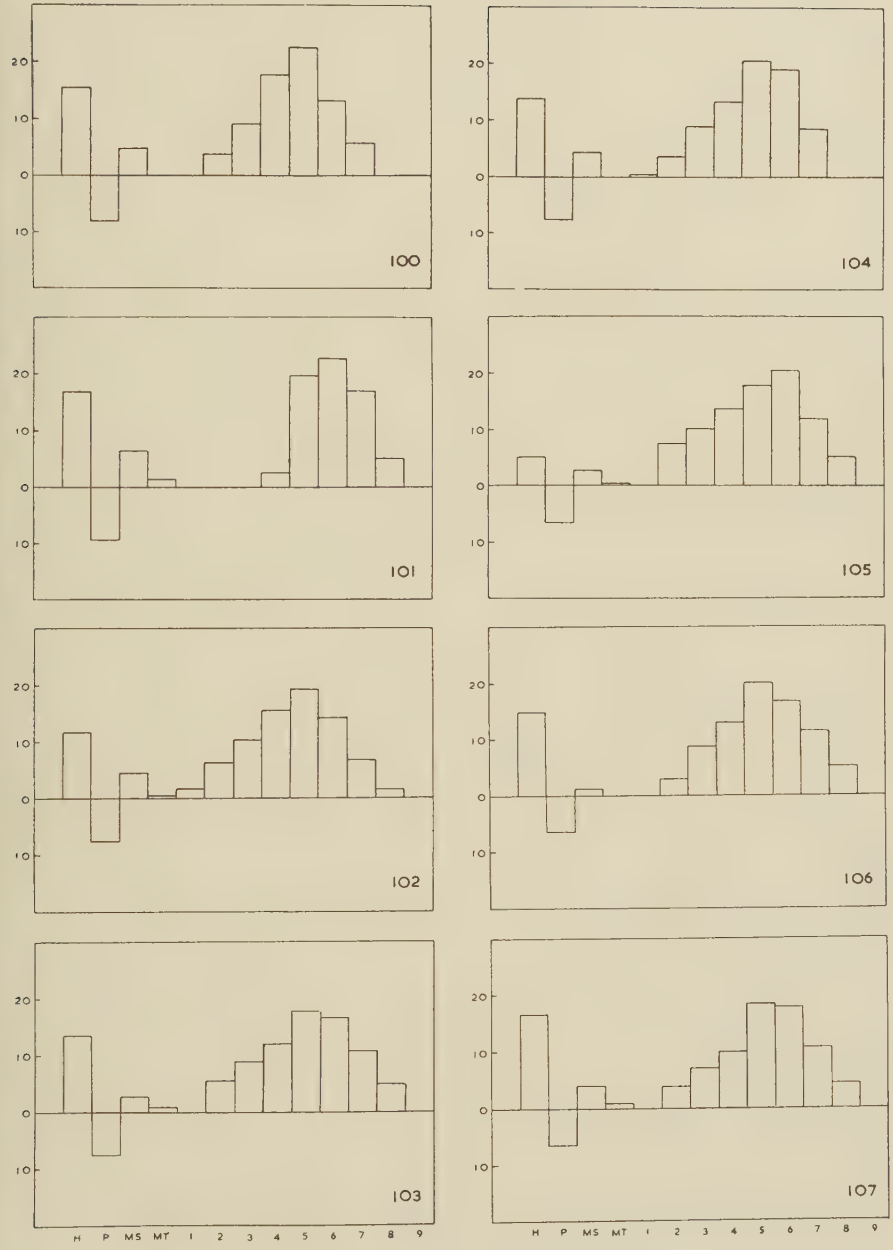

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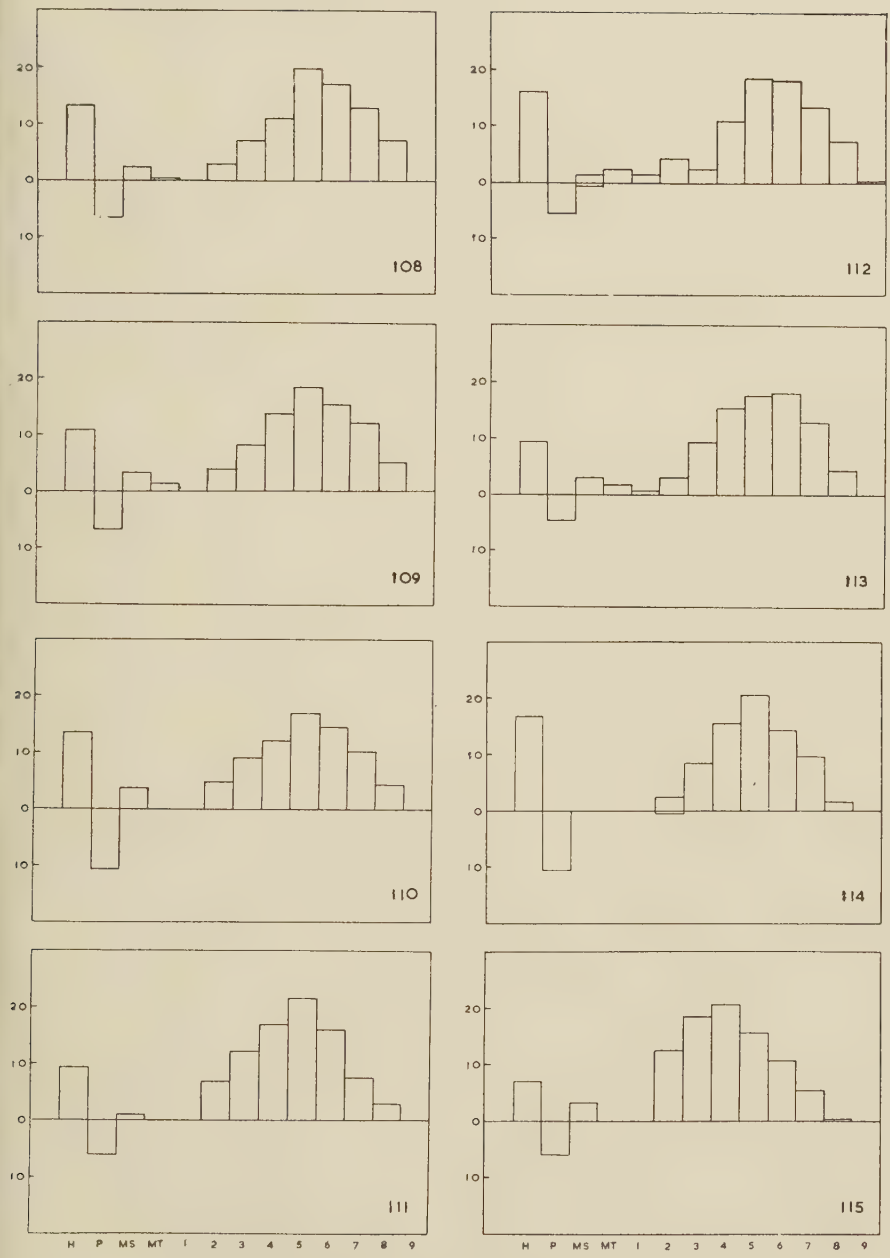

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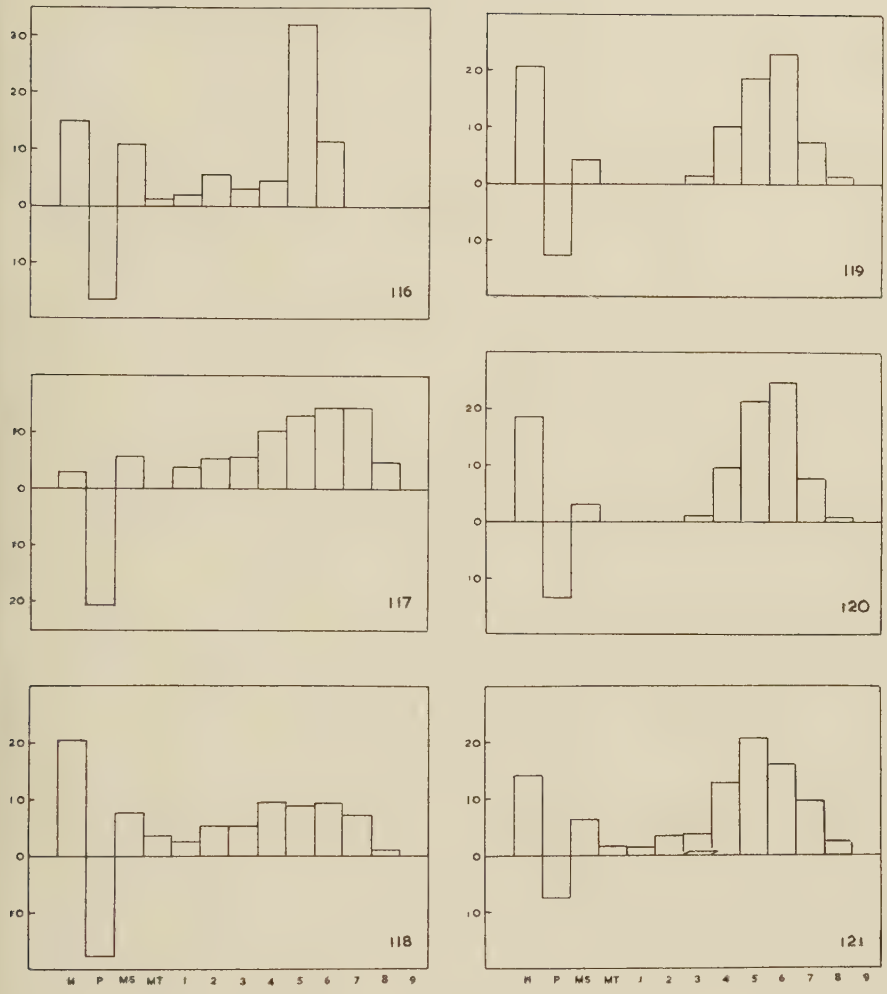

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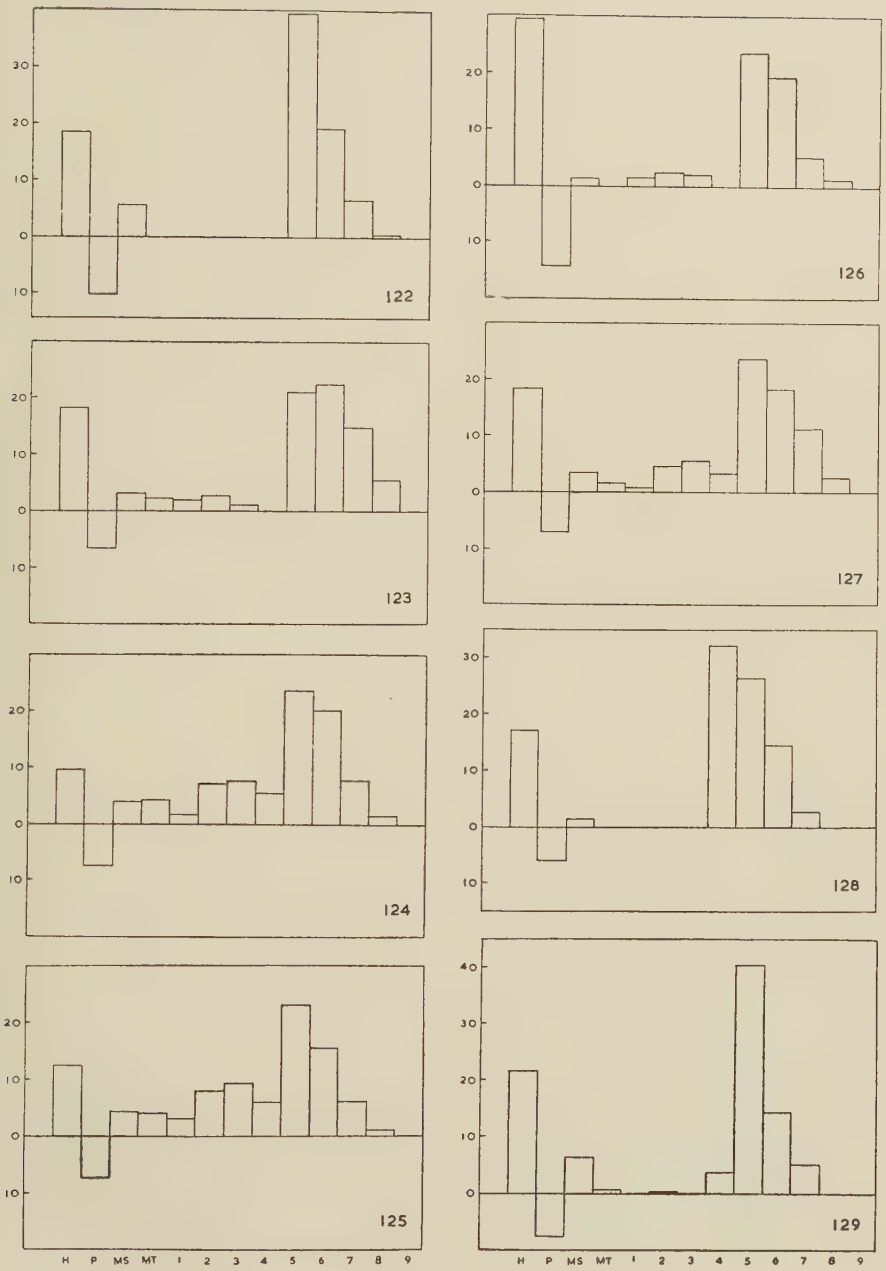

SLIFER—HEAT SENSITIVE AREAS

THE PATTERN OF SPECIALIZED HEAT-SENSITIVE AREAS ON THE SURFACE OF THE BODY OF ACRIDIDAE (ORTHOPTERA). PART II. THE FEMALES

BY ELEANOR H. SLIFER

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(Plates I–XVII, text-figures)

The pattern of specialized, heat-sensitive areas on the surface of the body of more than a hundred species of male Acrididae has been described in an article published recently in this journal (Slifer, 1953) and the reader is referred to it for a discussion of the historical background for these studies, the methods used in examining the heat-sensitive areas and for a list of the many persons to whom the writer is indebted for assistance in collecting and identifying the material used. With few exceptions the female specimens described in this paper were collected at the same time and place as were the males examined earlier. For a few species a single individual was obtained and so for these species data for one sex only can be given at this time.

Results

Subfamily Pamphaginae

One representative of this subfamily, *Saussurea stuhlmanniana,* from Shinyanga, Tanganyika, was examined. Like the male of this species the female is well provided with heat-sensitive areas. Fifteen pair, in all, were found. They are widely distributed over the body and occupy 1.81% of the total surface area. Outline drawings of the specialized areas are shown in text-figures 1 and 2 and a histogram which indicates their relative size and position on the body in figure 1. Additional data for this specimen are given in Table 1. An examination of text-figure 2 shows that the fenestrae on the abdominal terga of segments 3, 4, 5 and 6 are each composed of several parts. A similar condition was reported earlier for the male where, however, the fenestrae on segment 3 were of the undivided type. Fenestrae subdivided in such a complex manner were found in no other species of grasshopper or locust,

although, occasionally a crescent or fenestra separated into two or three pieces was seen.

A comparison of the data given here for the female with that given earlier for the male shows the female to have more and larger sensitive spots than does the male. The body surface of the female is over twice that of the male and the percentage of the total surface occupied by the spots in the female is about twice that in the male. A comparison of the histograms for the two shows the female to have approximately one-half of its entire sensitive surface on the underside of the body while the male has, roughly, one-quarter in this region.

Thomas (p. 3, and fig. 4, 1952) described and illustrated a pair of thin, oval patches which are located on the mesothoracic tergum of a female *Lamarckiana* sp., another member of this subfamily. These are, undoubtedly, the mesothoracic fenestrae. It would be most interesting to know whether the other heat-sensitive areas of *Lamarckiana* sp., especially those on the abdominal terga, are similar to those of *Saussurea stuhlmanniana.*

Subfamily Pyrgomorphinae

Nine females belonging to this subfamily were examined and a female *Pyrgomorpha* sp., from Keren, Eritrea, was chosen to represent the group. Its heat-sensitive areas are shown in text-figure 3 and its histogram is presented in figure 8. As is the case for all members of this subfamily, which were seen, this individual is generously provided with sensitive spots. The antennal crescents (A, text-fig. 3) are in two parts as were those described earlier for the male of this species. Two other different species of *Pyrgomorpha,* both from Wachiro, Eritrea, had crescents of the same kind, as did also a species of *Tanita* and an *Atractamorpha crenaticeps.* In these five females each crescent consists of a small patch which lies above the antennal membrane and a second and longer piece which lies close to the anterior and ventral edge of the compound eye. *Chrotogonus rendalli* and *Chrotogonus* sp. each have the uppermost portion only and *Pyrgomorphella arachidis* and *Phymateus pulcherrimus* have three-parted crescents with the third part lying medial to the antennal membrane. These unusual crescents separate the members of this subfamily very sharply from individuals of all other subfamilies.

In Table 1 the female Pyrgomorphinae have been arranged in ascending order, *first,* according to the number of pairs of specialized heat-sensitive areas which each possesses, *second,* according to the number of body-parts with such areas on them and, *third,* according to the percentage of the total body surface occupied by the spots. Those species with fewer and smaller spots, and with these not so widely scattered over the body, will be found near the beginning of the list and those with more and larger spots, which are distributed over a greater number of body-parts, will be found towards the end.

Subfamily Acridinae

Twenty-one species which belong to this subfamily were studied. A female *Acrida* sp., from Canberra, Australia, was chosen to represent the group and drawings of its antennal crescents and fenestrae may be seen in text-figure 4. This female possesses a small pair of crescents (A, text-figure 4) and so differs from the male of this species which lacks crescents entirely. These small crescents, in the female, lie above the antennal membrane and near the ocellus. Two other species of *Acrida,* both from Africa, and *Truxaloides brasiliensis* have crescents of a similar type. Among the other species studied *Amphitornus c. coloradus* has crescents somewhat larger than those shown for *Acrida* and no trace of crescents was found in *Mesopsis abbreviata.* All of the other members of this subfamily which were examined have large crescents of the type first reported for *Locusta migratoria migratorioides* (Slifer, 1951) and since found in many species of Acrididae.

An examination of figures 11 to 31 will show that all of the females of this subfamily have fenestrae which lie in the cervical membrane immediately in front of the anterior edge of the first prosternal plate. This particular pair of fenestrae occurs with great constancy throughout the entire family and very few species lack them. All but one of the acridine females (*Orthochtha* sp.) have one or more dorsal abdominal fenestrae. Lateral abdominal fenestrae occur in seven species (*Boopedon maculatum, Boopedon nubilum, Caledia captiva, Cryptobothrus chrysophorus, Eritettix s. simplex, Mermiria m. maculipennis* and *Mermiria maculipennis macclungi*) and ventral abdominal fenestrae in two species (*Caledia captiva* and *Cryptobothrus chrysophorus*).

The species of Acridinae studied have been arranged in Table 2 as were the species of Pyrgomorphinae in Table 1. It is easily apparent that the Acridinae, as a group, possess fewer and smaller heat-sensitive spots than do the Pyrgomorphinae. This was also found to be true for the males studied earlier. Two species, *Caledia captiva* and *Cryptobothrus chrysophorus,* are exceptional for they are well provided with sensitive areas.

Subfamily Oedipodinae

Forty-eight females of this subfamily were examined. It had been found earlier that the males of the Oedipodinae form an unusually homogeneous group and the same was found to be true for the females. The antennal crescents and fenestrae of a female *Dissosteira carolina,* from Iowa, are shown in text-figure 5 and its histogram may be seen in figure 49. This individual has 19 pairs of the specialized areas. These are distributed widely over the body, and 1.15% of the total body surface is occupied by them.

The antennal crescents of all but a few of the female Oedipodinae are quite similar to those shown for *Dissosteira carolina.* None of the oedipodinae females lacks crescents but in *Acrotylus variegatus, Austroicetes pusilla, Camnula pellucida* and *Trachyrhachis kiowa fuscifrons* they are comparatively small and lie only above the antennal membrane and do not extend ventrally along its anterior edge. In *Locustana pardalina* (gregarious phase) and in *Acrotylus longipes* the crescents are each composed of two parts. These, however, lie in the region occupied by the crescent in most species of Acrididae and so are quite unlike the two-parted crescents described for the Pyrgomorphinae.

All of the females of this subfamily are provided with prothoracic (cervical) fenestrae and all but one, *Encoptolophus s. sordidus,* possess lateral abdominal fenestrae. Ventral abdominal fenestrae are present in 30 individuals and absent in the rest.

In Table 3 the females studied have been arranged in order as were the species in Tables 1 and 2.

Subfamilies Romaleinae and Cyrtacanthacridinae

Forty-nine individuals of these subfamilies were examined. The antennal crescents and eighteen pairs of fenestrae of a female *Osmilia* sp., from Yurimaguas, Peru, are shown in text-figure 6 and

the histogram for this individual may be seen in figure 110. The heat-sensitive areas are basically similar to those of *Dissosteira carolina* and require no special comment. As was true for the males of this subfamily the group contains a number of species with spot patterns which differ markedly from those shown for *Osmilia* sp. The most extreme case of divergence is that of *Kosciuscola tristis,* an Australian species, found on Mount Kosciusko above the 5,000 foot line, and which has no specialized heat-sensitive areas, or, at least, none which can be found with the methods used in this study.

In *Melanoplus angustipennis, Melanoplus bivittatus, Melanoplus dawsoni, Melanoplus f. flavidus, Melanoplus foedus fluviatilis, Melanoplus m. mexicanus* and *Phoetaliotes nebrascensis* the antennal crescents are divided into two parts as were those of several species of Oedipodinae described in the preceding section. The crescents of *Phaulacridium nanum* are small and are confined to the region above the antennal membrane. In *Tetrataenia surinama* the crescents are large, horseshoe-shaped and extend ventrally on *both* sides of the antennal membrane. The male of *T. surinama* had crescents of this same very unusual shape.

An examination of the histograms in figures 80 to 127 will show that the majority of females of this subfamily are generously provided with fenestrae. The conspicuous exceptions are *Hypochlora alba, Melanoplus dawsoni, Melanoplus s. scudderi, Miramella mikado, Phoetaliotes nebrascensis* and *Praxibulus laminatus.* All of these, it may be noted, have short wings. *Kosciuscola tristis,* for which no histogram could be included since no heat-sensitive areas were found on it, also is short-winged. It may or may not be a coincidence that, with the exception of *Macrotona australis,* all of the females of this subfamily with fewer than ten pairs of special areas are either apterous or brachypterous.

All of the females of this subfamily which were examined are listed in Table 4 where they are arranged according to the same system employed for the other subfamilies.

Discussion

Several conspicuous differences are at once apparent when the means for the data for the heat-sensitive areas of the males are compared with those for the females (Table 5). The latter, *as a*

group, are better provided with the specialized areas and these tend to be more widely distributed over the dorsal, lateral and ventral surfaces than is the case with the males. The average percentage of the total body surface given over to them also is higher for the females. The distribution patterns of the spots on the body, as may be seen in the histograms of this and the earlier paper, differ markedly in the two sexes. In general, the females have more complex patterns than do the males. The possible significance of some of these differences will be considered below.

Spot Pattern and Egg-laying Habits.—Earlier it was suggested (Slifer, 1951, 1953) that the concentration of some of the largest pairs of fenestrae of the males on the fourth, fifth and sixth abdominal terga might aid in the protection of the spermatozoa in the reproductive organs which lie directly below these areas since the male germ cells are easily damaged by excessive heat. The terga of the abdomen in females are, in most species, also provided with fenestrae in the mid-dorsal line but they are relatively smaller in size and in addition, other fenestrae are found on the abdominal sterna and on the sides of some of the segments, close to the spiracles. Few males—only 12 of the 122 species examined—are provided with fenestrae on the underside of the abdomen and only one was found to have lateral abdominal fenestrae. The situation in the females is exactly opposite, for of the 128 specimens studied 100 have lateral fenestrae, ventral fenestrae or both. Since the difference between the sexes is so marked in this respect, it seems highly probable that it is associated with a difference in the habits of the two sexes. One obvious difference in their behavior results from the fact that the female must select a suitable site for egg-laying. During oviposition the abdomen is thrust deep into the soil. It seems likely that heat-sensitive areas which are located dorsally, laterally and ventrally on the abdomen would assist in preventing eggs from being laid in locations where they might be over-heated and so killed.

Spot Pattern and the Development of the Wings.—In the report on male Acrididae (Slifer, 1953) it was suggested that a correlation might exist between the occurrence of ventral abdominal fenestrae and the degree of development of the wings. The results were not conclusive and when the same statistical treatment was applied to the data for the females the results, again, were found to be

indecisive. While working with the specimens it has been difficult to avoid the impression that the pattern of sensitive spots and the extent of wing development are in some way related. A satisfactory analysis of the situation has, so far, eluded this observer.

Spot Pattern and Body Size.—A very significant correlation was found earlier between the number of pairs of specialized areas and the body size of males. Small males, in general, have fewer spots and large ones tend to have more of them. It was pointed out that large individuals, with their heavier and thicker body wall, would have more need of thin, specialized regions through which radiant heat could penetrate readily and so be detected quickly. A supporting bit of evidence for this suggestion is that members of the subfamily Acridinae appear to have a thinner body wall than do members of other subfamilies and, at the same time, the Acridinae, as a group, have fewer heat-sensitive spots than do the other subfamilies.

The mean number of the heat-sensitive spots present on all of the females studied was found to be 14 pairs and the mean total body surface area—which was used as an index of body size (Slifer, 1954b)—was found to be 707 mm.^{2} After these means had been determined all of the females were sorted into four groups. *Group 1* was made up of 26 females which possessed more than 14 pairs of sensitive spots and which had a surface area over 707 mm.^{2} *Group 2* contained 51 females which had 14, or fewer, pairs of sensitive spots and a surface area under 707 mm.^{2} *Group 3* was composed of 16 females which had 14, or fewer, spots and a surface area over 707 mm.^{2} *Group 4* had in it 35 females which had more than 14 specialized areas and a surface area less than 707 mm.^{2} The figures for the four groups were arranged in a 2×2 table and χ^2 calculated. χ^2 was found to be 4.3 and the probability that the distribution was due to chance alone lies between 0.05 and 0.02. A significant association thus exists in the females between body size and the number of heat-sensitive spots.

The data for all individuals of the two sexes were then combined in order to determine the association between size and the number of specialized areas for the family as a whole. The mean surface area for the sexes taken together was 575 mm. and the mean spot number found to be 12 pairs. The data for the entire group was

arranged in a 2×2 table, as had been that for each sex and χ^2 calculated. χ^2 was found to be 16.9 and the probability that chance alone was responsible for the distribution lies between 0.00004 and 0.00003. The reality of a strong association between size and spot number may thus be considered as established. An examination of the data in Tables 1 to 4 of this and the preceding paper (Slifer, 1953) brings out several other points of interest. No individual with a body surface area above 750 mm.^{2}—and there are 60 of these—has fewer than 10 pairs of sensitive spots. Among the smaller individuals—those with a surface under 750 mm.^{2}—the number of pairs of spots ranges from none to 25. This suggests strongly that the possession of a well-developed pattern of sensitive spots is much more important for the larger individuals than it is for the smaller ones.

Spot Pattern and the Number of Individuals of a Species.—It was pointed out earlier (Slifer, 1953) that the males of certain of those species of Acrididae which occur in such great numbers as to be of exceptional importance as agricultural pests are all provided with a large number of heat-sensitive spots and that these are widely distributed over the body. An examination of Tables 6 and 7 will show that the same statement applies to the females. We may conclude, then, that the possession of a well-developed pattern of sensitive spots may indeed be one of those factors—of which, naturally, there must be many—which contributes to the extraordinary success of these plague species. Those species, on the other hand, which lack such a favorable pattern, in either one or both sexes, are less able to respond with such sensitivity to favorable and unfavorable alterations in the temperature of their environment. If, upon further study, a species should be discovered which is poorly furnished with these specialized areas and this species is also one which occurs in such large numbers as to do great damage to vegetation, a modification of some of the conclusions drawn here would be necessary. As yet, however, no such species is known.

Summary

1. Specialized, heat-sensitive areas were found on the body surface of all except one of 128 species, subspecies and phase forms of female Acrididae examined. These represent six subfamilies and

were collected in many parts of the world in many different types of habitat.

2. Wide differences exist in the number, size, shape and distribution pattern of these sensitive spots in the different females studied.

3. In approximately 78% of the females, lateral abdominal fenestrae, ventral abdominal fenestrae, or both, are present in addition to those which occur on the dorsal surface of the abdomen. It is suggested that heat-sensitive areas on the abdomen aid the female in choosing soil of a suitable temperature for egg-laying.

4. No correlation was found between wing development and the presence of ventral abdominal fenestrae. It had been suggested earlier that there might be such a correlation, although a weak one, in the case of the males.

5. A significant correlation was found between the body surface area and the number of heat-sensitive spots possessed by an individual.

6. Those species of locusts and grasshoppers which occur in such great numbers as to be grave agricultural pests are all well provided with heat-sensitive areas.

TABLE 1

Heat-sensitive areas of one species of Pamphaginae and nine species of Pyrgomorphinae. Species of latter subfamily arranged in order according to number of pairs of special areas, number of body-parts which bear them and percentage of the total body surface occupied by them. All individuals are females.

Species	No. of pairs of spots	No. of body-parts with spots	% total surface occupied by spots	Total body surface ($mm.^2$)
Saussurea stuhlmanniana	15	9	1.81	2378
Pyrgomorphella arachidis	12	10	0.90	463
Chrotogonus rendalli	14	10	0.72	437
Pyrgomorpha sp.	19	12	0.87	261
Chrotogonus sp.	21	12	0.77	381
Pyrgomorpha sp.	22	12	1.07	247
Tanita sp.	22	12	1.48	606
Pyrgomorpha sp.	23	12	0.97	256
Phymateus pulcherrimus	24	12	1.73	1959
Atractomorpha crenaticeps	25	12	1.04	346

Table 2

Heat-sensitive areas of females of twenty-one species and subspecies of Acridinae. Species arranged in order according to number of pairs of these special areas, number of body-parts which bear them and percentage of the total body surface occupied by them.

Species	No. of pairs of spots	No. of body-parts with spots	% total surface occupied by spots	Total body surface ($mm.^2$)
Mesopsis abbreviata	4	4	0.04	687
Orthochtha sp.	4	4	0.17	655
Ageneotettix deorum	5	5	0.19	250
Syrbula admirabilis	6	6	0.17	577
Orphulella speciosa	6	6	0.31	232
Drepanoptera femoratum	8	8	0.48	312
Dichromorpha viridis	9	7	0.56	338
Eritettix s. simplex	9	8	0.63	292
Amphitornus c. coloradus	9	9	0.47	302
Orphulella sp.	9	9	0.49	201
Boopedon nubilum	10	8	0.66	983
Acrida sp.	10	10	0.24	1391
Acrida bicolor	10	10	0.45	1249
Acrida sp.	10	10	0.68	880
Mermiria m. maculipennis	11	9	1.23	885
Duronia tricolor	11	11	0.60	649
Truxaloides brasiliensis	11	11	0.61	1174
Mermiria maculipennis macclungi	12	10	1.12	447
Boopedon maculatum	13	10	0.71	1037
Cryptobothrus chrysophorus	15	10	1.18	213
Caledia captiva	17	9	0.90	467

Table 3

Heat-sensitive areas of females of forty-eight species, subspecies and phase, geographic and color forms of Oedipodinae. Species arranged in order according to number of pairs of these special areas, number of body-parts which bear them and percentage of the total body surface occupied by them.

Species	No. of pairs of spots	No. of body-parts with spots	% total surface occupied by spots	Total body surface (mm.²)
Austroicetes pusilla	10	8	0.31	282
Encoptolophus s. sordidus	10	10	0.48	472
Oedaleus australis	11	7	0.63	398
Trachyrhachis kiowa fuscifrons	11	8	0.40	273
Rehnita gracilipes	12	8	1.03	371
Arphia pseudonietana	13	8	0.69	668
Acrotylus sp.	13	9	0.47	258
Acrotylus variegatus	13	10	0.53	262
Locustana pardalina (phase gregaria)	13	11	0.49	1000
Oedaleus senegalensis	13	11	0.68	600
Locustana pardalina (phase solitaria)	13	11	0.75	579
Trilophidia sp.	13	11	0.75	247
Oedaleus senegalensis	13	11	0.77	630
Aiolopus sp.	13	11	0.77	354
Arphia sulphurea	14	8	1.24	539
Acrotylus patruelis	14	9	0.71	374
Acrotylus longipes	14	10	0.86	258
Gastrimargus africanus	14	10	0.90	1328
Chortophaga viridifasciata	14	11	0.68	600
Arphia xanthoptera	14	11	0.75	891
Aiolopus sp.	14	11	0.81	450
Aiolopus sp.	14	11	1.05	356
Psinidia f. fenestralis	15	10	0.44	377
Sphingonotus savignyi	15	11	0.63	536
Hadrotettix trifasciatus	15	11	0.98	1012
Aiolopus tamulus	15	11	1.16	347
Spharagemon collare	16	10	0.60	482
Oedaleus citrinus	16	10	0.98	790
Tmetonota peregrina	16	11	0.81	404
Morphacris fasciata	16	11	0.91	416
Aiolopus savignyi	16	11	1.01	373
Gastrimargus musicus	16	11	1.14	787
Derotmema haydenii laticinctum	16	11	1.23	328
Morphacris fasciata	16	11	1.26	381
Locusta migratoria migratorioides (phase solitaria)	16	11	1.27	1568

TABLE 3 (*continued*)

Species	No. of pairs of spots	No. of body-parts with spots	% total surface occupied by spots	Total body surface (mm.²)
Camnula pellucida	16	11	1.49	443
Heliastus venezuelae	17	10	1.35	682
Encoptolophus s. subgracilis	17	11	1.26	429
Locusta migratoria migratorioides (phase solitaria)	17	12	1.12	1266
Locusta migratoria migratorioides (phase gregaria)	17	12	1.14	1274
Spharagemon bolli	18	10	1.11	696
Conozoa s. sulcifrons	18	11	1.17	458
Pycnodictya miniatiapennis	18	11	1.28	904
Humbe tenuicornis	18	11	1.29	757
Hippiscus rugosus	18	11	1.29	866
Pardalophora apiculata	18	11	1.51	1337
Trimerotropis p. pallidipennis	18	12	1.02	646
Dissosteira carolina	19	11	1.15	933

TABLE 4

Heat-sensitive areas of females of forty-nine species, subspecies and phase forms of Romaleinae and Cyrtacanthacridinae. Species arranged in order according to number of pairs of these special areas, number of body-parts which bear them and percentage of the total body surface occupied by them.

Species	No. of pairs of spots	No. of body-parts with spots	% total surface occupied by spots	Total body surface (mm.²)
Kosciuscola tristis	0	0	0	410
Miramella mikado	3	3	0.09	749
Hypochlora alba	4	4	0.18	296
Phoetaliotes nebrascensis	4	4	0.19	381
Praxibulus laminatus	4	4	0.42	271
Melanoplus dawsoni	5	5	0.12	253
Melanoplus s. scudderi	6	5	0.28	325
Paraidemona punctata	8	7	0.46	323
Campylacantha o. olivacea	8	8	0.42	498
Macrotona australis	8	8	0.56	317
Paratylotropidia brunneri	8	8	0.75	597
Schistocerca alutacea	10	7	0.30	1112

TABLE 4 (*continued*)

Species	No. of pairs of spots	No. of body-parts with spots	% total surface occupied by spots	Total body surface (mm.²)
Melanoplus keeleri luridus	10	8	0.47	482
Schistocerca lineata	10	9	0.45	1195
Melanoplus d. differentialis	10	10	0.32	827
Hesperotettix v. viridis	10	10	0.69	472
Melanoplus f. flavidus	11	8	0.44	324
Melanoplus differentialis nigricans	11	11	0.46	956
Phaulacridium nanum	12	11	0.36	123
Melanoplus bivittatus	13	8	0.56	750
Phaulacridium vittatum	13	11	0.67	198
Melanoplus foedus fluviatilus	14	8	0.56	488
Melanoplus m. mexicanus	14	9	0.51	393
Brachystola magna	14	9	1.03	3052
Melanoplus glaucipes	14	10	0.51	511
Caloptenopsis meruensis	15	10	1.02	704
Tetrataenia surinama	15	12	1.19	357
Romalea microptera	15	12	1.57	2717
Melanoplus f.-r. femur-rubrum	16	9	0.70	413
Melanoplus angustipennis	16	11	0.83	335
Urnisa guttulosa	16	11	0.88	425
Hesperotettix speciosus	17	10	0.54	724
Abracris sp.	17	12	0.82	289
Thisoicetrus annulosus	18	11	0.79	802
Peakesia fuscomaculata	18	11	0.93	507
Cataloipus sp.	18	11	0.95	1609
Schistocerca sp.	18	11	1.27	1416
Schistocerca gregaria (phase gregaria)	18	12	1.20	1582
Nomadacris septemfasciata	18	12	1.49	1865
Schistocerca gregaria (phase solitaria)	18	12	1.50	2003
Dactylotum pictum	19	10	1.77	655
Osmilia sp.	19	11	1.23	497
Catantops axillaris	19	12	1.37	1060
Catantops sp.	20	12	1.35	463
Catantops curvicercus	20	12	1.55	397
Cyrtacanthacris tatarica abyssinica	20	12	1.62	1056
Schistocerca a. americana	20	12	1.72	1364
Cyrtacanthacris t. tatarica	21	12	1.78	2157
Cyrtacanthacris t. tatarica	21	12	2.26	1616

Table 5

Means for number of heat-sensitive spots, number of body parts which bear them, percentage of the total surface occupied by them and total body surface area of male and female Acrididae.

Subfamily	Mean no. pairs of spots	Mean no. body-parts with spots	Mean % total surface occupied by spots	Mean total surface ($mm.^2$)
Pamphaginae				
1 male	14	9	0.91	1048
1 female	15	9	1.81	2378
Pyrgomorphinae				
7 males	13	11	0.51	380
9 females	20	12	1.06	551
Acridinae				
20 males	8	8	0.43	304
21 females	10	9	0.57	630
Oedipodinae				
50 males	10	10	0.66	390
48 females	15	10	0.92	618
Romaleinae and Cyrtacanthacridinae				
52 males	11	11	0.85	551
49 females	13	9	0.84	823
130 males (total)	10	10	0.69	447
128 females (total)	14	10	0.85	707

Table 6

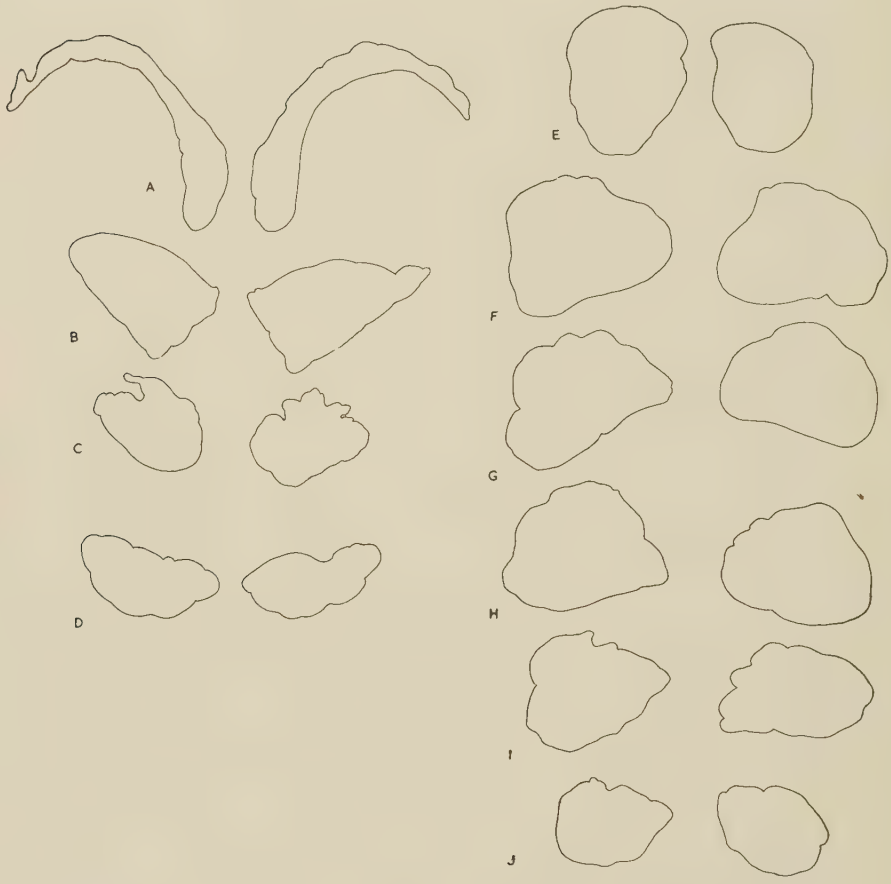
The heat-sensitive areas of the females of some of the major plague species of locusts of the world.

Species	No. of pairs of spots	No. of body-parts with spots	% total surface occupied by spots	Total body surface (mm.²)
Locustana pardalina (phase gregaria)	13	11	0.49	1000
Locustana pardalina (phase solitaria)	13	11	0.75	579
Locusta migratoria migratorioides (phase solitaria)	16	11	1.27	1568
Locusta migratoria migratorioides (phase gregaria)	17	12	1.14	1274
Locusta migratoria migratorioides (phase solitaria)	17	12	1.12	1266
Schistocerca gregaria (phase gregaria)	18	12	1.20	1582
Nomadacris septemfasciata	18	12	1.49	1865
Schistocerca gregaria (phase solitaria)	18	12	1.50	2003

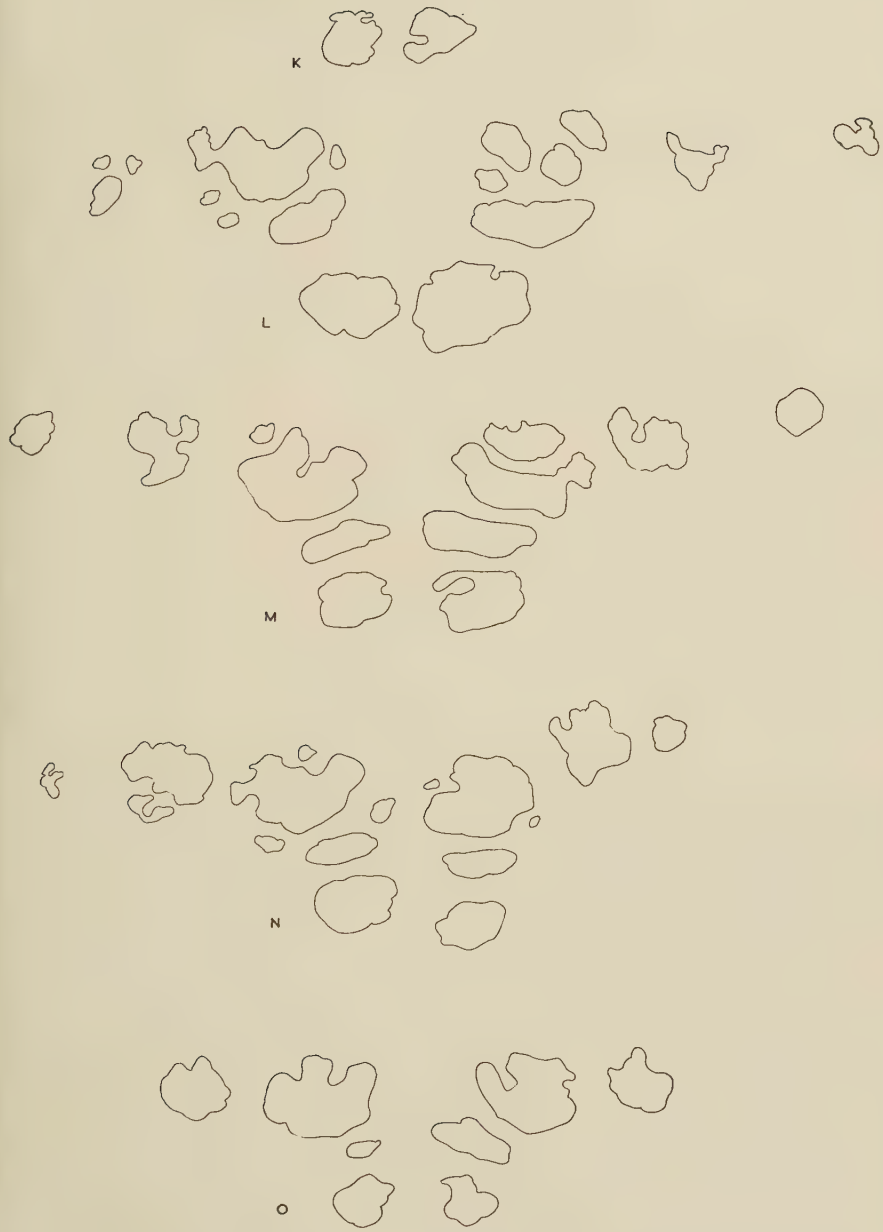
Table 7

The heat-sensitive areas of females of North American grasshoppers which are of importance as agricultural pests.

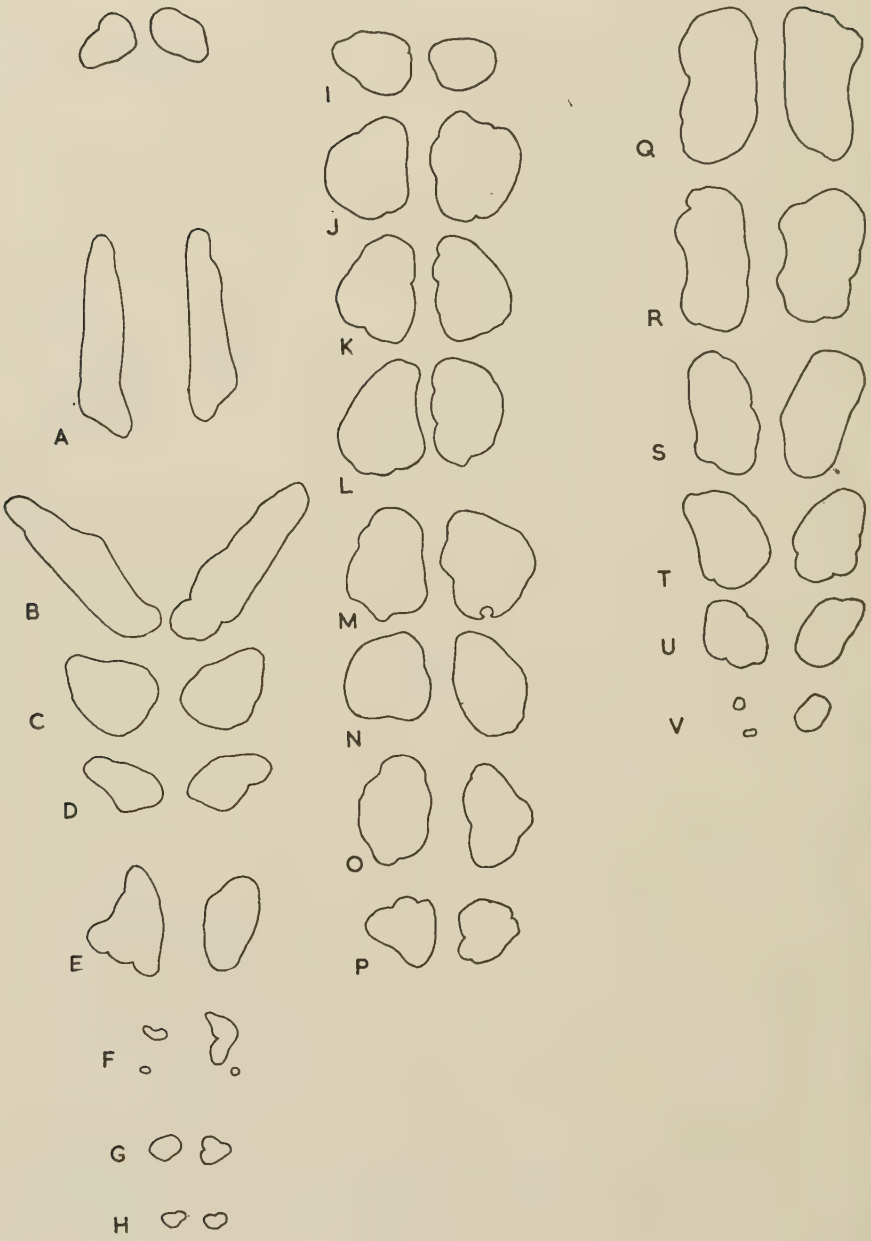
Species	No. of pairs of spots	No. of body-parts with spots	% total surface occupied by spots	Total body surface (mm.²)
Melanoplus keeleri luridus	10	8	0.47	482
Melanoplus d. differentialis	10	10	0.32	827
Melanoplus differentialis nigricans	11	11	0.46	956
Melanoplus bivittatus	13	8	0.56	750
Melanoplus m. mexicanus	14	9	0.51	393
Melanoplus f.-r. femur-rubrum	16	9	0.70	413
Camnula pellucida	16	11	1.49	443



Text-figure 1.—Outline drawings of the heat-sensitive areas of a female *Saussurea stuhlmanniana* Karsch from Shinyanga, Tanganyika. A, antennal crescents, which partially encircle the antennal sockets; B, prothoracic (cervical) fenestrae, which lie in the cervical membrane near the anterior edge of the first prosternal plate; C, prothoracic fenestrae which are located on the first prosternal plate lateral to the prosternal spine; D, mesothoracic fenestrae, which are located near the anterior border of the scutum in the dorsal mid-line; E, ventral fenestrae in lateral, anterior corners of sternum of second abdominal segment; F, same for third segment; G, same for fourth segment; H, same for fifth segment; I, same for sixth segment; J, same for seventh segment. Compare with histogram, plate I, fig. 1. (See text-figure 2 for dorsal abdominal fenestrae of this female.) × 12.

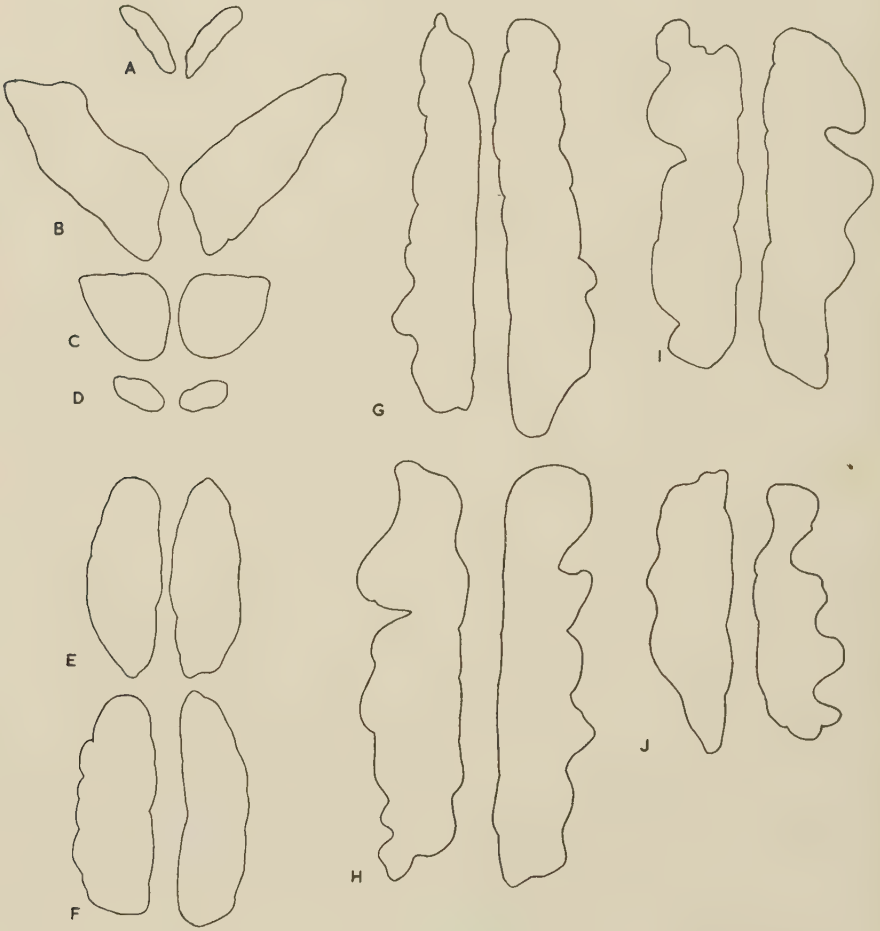


Text-figure 2.—Outline drawings of the fenestrae which are located in the dorsal mid-line of the abdomen of a female *Saussurea stuhlmanniana* Karsch. (Other heat-sensitive areas of this individual are shown in text-figure 1) K, dorsal fenestrae on second abdominal segment; L, same for third segment; M, same for fourth segment; N, same for fifth segment; O, same for sixth segment. Compare with histogram, plate I, fig. 1. × 12.

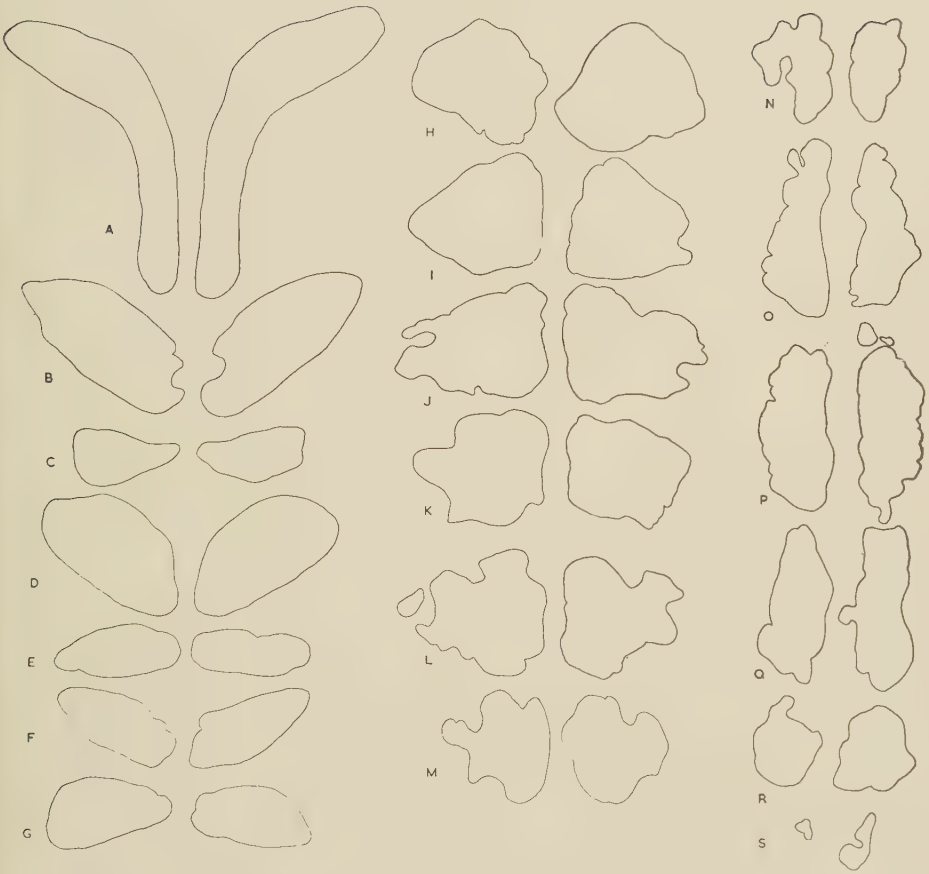


Text-figure 3

Text-figure. 3.—Outline drawings of the heat-sensitive areas of a female *Pyrgomorpha* sp. from Keren, Eritrea. A, two-parted antennal crescents each with a dorsal portion which lies above the antennal membrane and a ventral portion which lies near the anterior, ventral corner of the compound eye; B, prothoracic (cervical) fenestrae, which lie in the cervical membrane just in front of the first prosternal plate; C, mesothoracic fenestrae, which are located near the anterior border of the scutum in the dorsal mid-line; D, metathoracic fenestrae, which are located near the anterior border of the scutum in the dorsal mid-line; E, lateral fenestrae, which are located on the second abdominal segment near the spiracles; F, same for the third segment; G, same for the fourth segment; H, same for the fifth segment; I, dorsal fenestrae which are located on the second abdominal segment in the dorsal mid-line; J, same for the third segment; K, same for fourth segment; L, same for fifth segment; M, same for sixth segment; N, same for seventh segment; O, same for eighth segment; P, same for ninth segment; Q, ventral fenestrae, which are located in lateral, anterior corners of the sternum of the second abdominal segment; R, same for third segment; S, same for fourth segment; T, same for fifth segment; U, same for sixth segment; V, same for seventh segment. Compare with histogram, plate I, fig. 8. X 38.



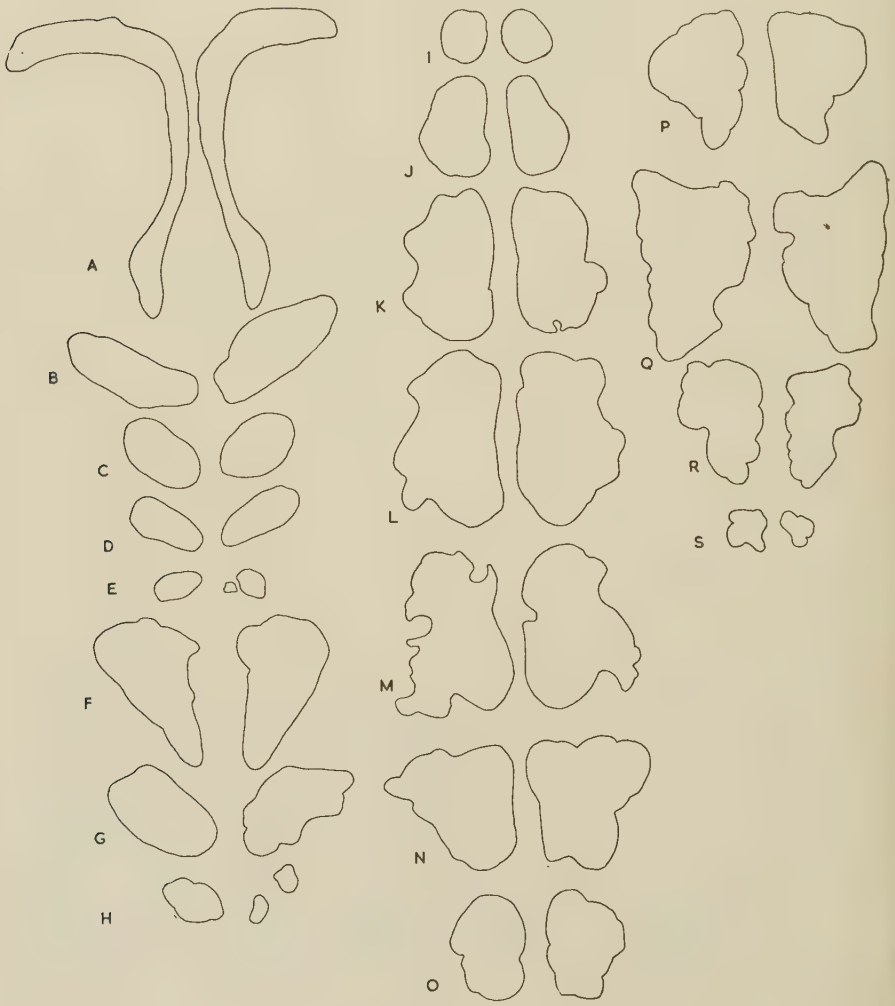
Text-figure 4.—Outline drawings of the heat-sensitive areas of a female *Acrida* sp. from Canberra, A.C.T., Australia. A, antennal crescents, which lie above the antennal membranes; B, prothoracic (cervical) fenestrae, which lie in the cervical membrane near the anterior edge of the first prosternal plate; C, mesothoracic fenestrae, which are located near the anterior border of the scutum in the dorsal mid-line; D, metathoracic fenestrae, which are located near the anterior border of the scutum in the dorsal mid-line; E, dorsal fenestrae which are located on the first abdominal segment in the dorsal mid-line; F, same for second segment; G, same for third segment; H, same for fourth segment; I, same for fifth segment; J, same for sixth segment. Compare with histogram, plate II, fig. 12. × 29.



Text-figure 5.—Outline drawings of the heat-sensitive areas of a female *Dissosteira carolina* (Linnaeus) from Iowa. A, antennal crescents, which partially encircle the antennal sockets; B, prothoracic (cervical) fenestrae, which lie in the cervical membrane near the anterior border of the first prosternal plate; C, prothoracic fenestrae which are located on the first prosternal plate; D, mesothoracic fenestrae, which are located near the anterior border of the scutum in the dorsal mid-line; E, mesothoracic fenestrae, which are located near the posterior border of the basisternum in the ventral mid-line; F, metathoracic fenestrae, which are located near the anterior border of the scutum in the dorsal mid-line; G, metathoracic fenestrae, which are located near the anterior border of the basisternum in the ventral mid-line; H, dorsal fenestrae which are located on the first

Text-fig. 5 (*cont.*)

abdominal segment in the dorsal mid-line; I, same for second segment; J, same for third segment; K, same for fourth segment; L, same for fifth segment; M, same for sixth segment; N, same for seventh segment; O, lateral fenestrae which are located on the second abdominal segment close to the spiracles; P, same for third segment; Q, ventral fenestrae which are located in the lateral, anterior corners of the sternum of the second abdominal segment; R, same for third segment; S, same for fourth segment. Compare with histogram, plate VII, fig. 49. × 22.



Text-figure 6

Text-figure 6.—Outline drawings of the heat-sensitive areas of a female *Osmilia* sp. from Yurimaguas, Peru. A, antennal crescents, which partially encircle the antennal sockets; B, prothoracic (cervical) fenestrae, which lie in the cervical membrane near the anterior border of the first prosternal plate; C, mesothoracic fenestrae, which are located near the anterior border of the scutum in the dorsal mid-line; D, metathoracic fenestrae, which are located near the anterior border of the scutum in the dorsal mid-line; E, metathoracic fenestrae, which are located near the anterior border of the basisternum in the ventral mid-line; F, ventral fenestrae which are located in the lateral, anterior corners of the sternum of the second abdominal segment; G, same for third segment; H, same for fourth segment; I, dorsal fenestrae which are located on the first abdominal segment in the dorsal mid-line; J, same for second segment; K, same for third segment; L, same for fourth segment; M, same for fifth segment; N, same for sixth segment; O, same for seventh segment; P, lateral fenestrae which are located on the second abdominal segment close to the spiracles; Q, same for the third segment; R, same for fourth segment; S, same for fifth segment Compare with histogram, plate XVI, fig. 110. × 27.

Explanation of Plates

Histograms showing pattern of heat-sensitive areas for various female Acrididae. Zero base-line of each divided into thirteen equal spaces. Each space represents a body-part, H, head; P, prothorax; MS, mesothorax; MT, metathorax; 1 to 9, abdominal segments one to nine. Rectangles extending vertically above base-line represent dorsal and dorso-lateral heat-sensitive areas and those extending below it represent ventral heat-sensitive areas. Parallelograms which slant to right above base-line represent lateral heat-sensitive areas which are located near the abdominal spiracles. Parallelograms which slant to left below base-line represent heat-sensitive areas located on the first prosternal plate. Percentage of total heat-sensitive area which is present on each region of each body-part indicated by height of rectangle or parallelogram.

Plate I

Subfamilies Pamphaginae and Pyrgomorphinae

Fig. 1. *Saussurea stuhlmanniana* Karsch, Shinyanga, Tanganyika.
Fig. 2. *Atractomorpha crenaticeps* (Blanchard), Canberra, A.C.T., Australia.
Fig. 3. *Chrotogonus rendalli* Kirby, Shinyanga, Tanganyika.
Fig. 4. *Chrotogonus* sp., Wachiro, Eritrea.
Fig. 5. *Phymateus pulcherrimus* Bolívar, Ghinda, Eritrea.
Fig. 6. *Pyrgomorpha* sp., Wachiro, Eritrea.
Fig. 7. *Pyrgomorpha* sp., Wachiro, Eritrea.
Fig. 8. *Pyrgomorpha* sp., Keren, Eritrea.

Plate II

Subfamilies Pyrgomorphinae and Acridinae

Fig. 9. *Pyrgomorphella arachidis* Dirsh, Shinyanga, Tanganyika.
Fig. 10. *Tanita* sp., Shinyanga, Tanganyika.
Fig. 11. *Acrida bicolor* Thunberg, Cum Ceua, Eritrea.
Fig. 12. *Acrida* sp., Canberra, A.C.T., Australia.
Fig. 13. *Acrida* sp., Shinyanga, Tanganyika.
Fig. 14. *Ageneotettix deorum* (Scudder), Boulder, Colorado.
Fig. 15. *Amphitornus coloradus coloradus* (Thomas), Boulder, Colorado.
Fig. 16. *Boopedon maculatum* Caudell, Waxahachie, Texas.

Plate III

Subfamily Acridinae

Fig. 17. *Boopedon nubilum* (Say), Canadian Brakes, Dumas, Texas.
Fig. 18. *Caledia captiva* (Fabricius), Canberra, A.C.T., Australia.
Fig. 19. *Cryptobothrus chrysophorus* Rehn, Canberra, A.C.T., Australia.
Fig. 20. *Dichromorpha viridis* (Scudder), Iowa.
Fig. 21. *Drepanoptera femoratum* (Scudder), Canadian Brakes, Dumas, Texas.

Fig. 22. *Duronia tricolor* Karny, Sabarghuma Plain, Eritrea.
Fig. 23. *Eritettix simplex simplex* (Scudder), Iowa.
Fig. 24. *Mermiria maculipennis maculipennis* Bruner, Colorado (?).

PLATE IV

Subfamily Acridinae

Fig. 25. *Mermiria maculipennis macclungi* Rehn, Iowa.
Fig. 26. *Mesopsis abbreviata* Palisot, Shinyanga, Tanganyika.
Fig. 27. *Orphulella speciosa* Scudder, Iowa.
Fig. 28. *Orphulella* sp., Yurimaguas, Peru.
Fig. 29. *Orthochtha* sp., Shinyanga, Tanganyika.

PLATE V

Subfamilies Acridinae and Oedipodinae

Fig. 30. *Syrbula admirabilis* (Uhler), Iowa.
Fig. 31. *Truxaloides brasiliensis* Latreille, Shinyanga, Tanganyika.
Fig. 32. *Acrotylus longipes* (Charpentier), Wachiro, Eritrea.
Fig. 33. *Acrotylus patruelis* Herrich-Schaffer, Shinyanga, Tanganyika.
Fig. 34. *Acrotylus variegatus* Blanchard, Keren, Eritrea.
Fig. 35. *Acrotylus* sp., Asmara, Eritrea.

PLATE VI

Subfamily Oedipodinae

Fig. 36. *Aiolopus savignyi* (Krauss), Wachiro, Eritrea.
Fig. 37. *Aiolopus tamulus* (Fabricius), Canberra, A.C.T., Australia.
Fig. 38. *Aiolopus* sp., Asmara, Eritrea.
Fig. 39. *Aiolopus* sp., Sabarghuma Plain, Eritrea.
Fig. 40. *Aiolopus* sp., Shinyanga, Tanganyika.
Fig. 41. *Arphia pseudonietana* (Thomas), Boulder, Colorado.
Fig. 42. *Arphia sulphurea* (Fabricius), Rochester, Iowa.
Fig. 43. *Arphia xanthoptera* (Burmeister), Wilmer, Texas.

PLATE VII

Subfamily Oedipodinae

Fig. 44. *Austroicetes pusilla* (Walker), Canberra, A.C.T., Australia.
Fig. 45. *Camnula pellucida* (Scudder), Colorado.
Fig. 46. *Chortophaga viridifasciata* (DeGeer), Rochester, Iowa.
Fig. 47. *Conozoa sulcifrons sulcifrons* Scudder, Phoenix, Arizona.
Fig. 48. *Derotmema haydenii laticinctum* Scudder, Phoenix, Arizona.
Fig. 49. *Dissosteira carolina* (Linnaeus), Iowa. (Bar indicating fenestrae with 7.2 % sensitive area in dorsal mid-line of abdominal segment two inadvertently omitted from histogram.)
Fig. 50. *Encoptolophus sordidus sordidus* (Burmeister), Iowa.
Fig. 51. *Encoptolophus subgracilis subgracilis* Caudell, Phoenix, Arizona.

Plate VIII

Subfamily Oedipodinae

Fig. 52. *Gastrimargus africanus* Saussure, Shinyanga, Tanganyika.
Fig. 53. *Gastrimargus musicus* (Fabricius), Canberra, A.C.T., Australia.
Fig. 54. *Hadrotettix trifasciatus* (Say), source (?).
Fig. 55. *Heliastus venezuelae* (Saussure) Cristobal, Canal Zone.
Fig. 56. *Hippiscus rugosus* (Scudder), Iowa.
Fig. 57. *Humbe tenuicornis* Schaum, Shinyanga, Tanganyika.
Fig. 58. *Locusta migratoria migratorioides* (Reiche & Fairmaire), phase solitaria, Wachiro, Eritrea.
Fig. 59. *Locusta migratoria migratorioides* (Reiche & Fairmaire), phase solitaria, Anti-Locust Research Centre, London, laboratory-bred.

Plate IX

Subfamily Oedipodinae

Fig. 60. *Locusta migratoria migratorioides* (Reiche & Fairmaire), phase gregaria, Anti-Locust Research Centre, London, laboratory-bred.
Fig. 61. *Locustana pardalina* (Walker) phase solitaria, Pretoria, South Africa, laboratory-bred.
Fig. 62. *Locustana pardalina* (Walker) phase gregaria, Pretoria, South Africa, laboratory-bred.
Fig. 63. *Morphacris fasciata* Thunberg, Shinyanga, Tanganyika.
Fig. 64. *Morphacris fasciata* Thunberg, Sabarghuma Plain, Eritrea. Red-winged form.
Fig. 65. *Oedaleus australis* Saussure, Canberra, A.C.T., Australia.
Fig. 66. *Oedaleus citrinus* Saussure, Shinyanga, Tanganyika.
Fig. 67. *Oedaleus senegalensis* Krauss, Sabarghuma Plain, Eritrea.

Plate X

Subfamily Oedipodinae

Fig. 68. *Oedaleus senegalensis* Krauss, Shinyanga, Tanganyika.
Fig. 69. *Pardalophora apiculata* (Harris), Rochester, Iowa.
Fig. 70. *Psinidia fenestralis fenestralis* (Serville), Iowa.
Fig. 71. *Pycnodictya miniatiapennis* Karsch, Shinyanga, Tanganyika.
Fig. 72. *Rehnita gracilipes* (Caudell), Phoenix, Arizona.
Fig. 73. *Spharagemon bolli* Scudder, Iowa.
Fig. 74. *Spharagemon collare* (Scudder), Iowa.
Fig. 75. *Sphingonotus savignyi* Saussure, Wachiro, Eritrea.

Plate XI

Subfamilies Oedipodinae, Romaleinae and Cyrtacanthacridinae

Fig. 76. *Tmetonota peregrina* Karny, Shinyanga, Tanganyika.
Fig. 77. *Trachyrhachis kiowa fuscifrons* (Stål), Iowa.
Fig. 78. *Trilophidia* sp., Sabarghuma Plain, Eritrea.
Fig. 79. *Trimerotropis pallidipennis pallidipennis* (Burmeister), Phoenix, Arizona.

Fig. 80. *Abracris* sp., Yurimaguas, Peru.
Fig. 81. *Brachystola magna* (Girard), Wichita Falls, Texas.
Fig. 82. *Caloptenopsis meruensis* Sjöstedt, Shinyanga, Tanganyika.
Fig. 83. *Campylacantha olivacea olivacea* (Scudder), Iowa.

PLATE XII

Subfamily Cyrtacanthacridinae

Fig 84. *Cataloipus* sp., Shinyanga, Tanganyika.
Fig. 85. *Catantops axillaris* (Thunberg), Jebel Halibai, Eritrea.
Fig. 86. *Catantops curvicercus* Miller, Shinyanga, Tanganyika.
Fig. 87. *Catantops* sp., Shinyanga, Tanganyika.
Fig. 88. *Cyrtacanthacris tatarica tatarica* (Linnaeus), Wachiro, Eritrea.
Fig. 89. *Cytacanthacris tatarica tatarica* (Linnaeus), Shinyanga, Tanganyika.
Fig. 90. *Cyrtacanthacris tatarica abssyinica* Uvarov, Asmara, Eritrea.
Fig. 91. *Dactylotum pictum* (Thomas), source (?).

PLATE XIII

Subfamily Cyrtacanthacridinae

Fig. 92. *Hesperotettix speciosus* Scudder, source (?).
Fig. 93. *Hesperotettix viridis viridis* (Thomas), Texas.
Fig. 94. *Hypochlora alba* (Dodge), Boulder, Colorado.
Fig. 95. *Macrotona australis* (Walker), Canberra, A.C.T., Australia.
Fig. 96. *Melanoplus angustipennis* (Dodge), Iowa.
Fig. 97. *Melanoplus bivittatus* (Say), Iowa.
Fig. 98. *Melanoplus dawsoni* (Scudder), Iowa.

PLATE XIV

Subfamily Cyrtacanthacridinae

Fig. 99. *Melanoplus differentialis differentialis* (Thomas), Iowa, laboratory-bred.
Fig. 100. *Melanoplus differentialis nigricans* Cockerell, Waxahachie, Texas.
Fig. 101. *Melanoplus femur-rubrum femur-rubrum* (DeGeer), Iowa.
Fig. 102. *Melanoplus flavidus flavidus* Scudder, Iowa.
Fig. 103. *Melanoplus foedus fluviatilis* Bruner, Iowa.
Fig. 104. *Melanoplus glaucipes* (Scudder), Tehacuana Creek Bottoms, Waco, Texas.
Fig. 105. *Melanoplus keeleri luridus* (Dodge), Iowa.

PLATE XV

Subfamily Cyrtacanthacridinae

Fig. 106. *Melanoplus mexicanus mexicanus* (Saussure), Boulder, Colorado.
Fig. 107. *Melanoplus scudderi scudderi* (Uhler), Iowa.
Fig. 108. *Miramella mikado* (Bolívar), Formosa (?).
Fig. 109. *Nomadacris septemfasciata* Serville, Shinyanga, Tanganyika.

Plate XVI

Subfamily Cyrtacanthacridinae

Fig. 110. *Osmilia* sp., Yurimaguas, Peru.
Fig. 111. *Paraidemona punctata* (Stål), Tehacuana Creek Bottoms, Waco, Texas.
Fig. 112. *Paratylotropidia brunneri* Scudder, Iowa.
Fig. 113. *Peakesia fuscomaculata* Sjöstedt, Canberra, A.C.T., Australia.
Fig. 114. *Phaulacridium nanum* Sjöstedt, Canberra, A.C.T., Australia.
Fig. 115. *Phaulacridium vittatum* Sjöstedt, Canberra, A.C.T., Australia.

Plate XVII

Subfamilies Romaleinae and Cyrtacanthacridinae

Fig. 116. *Phoetaliotes nebrascensis* (Thomas), Iowa.
Fig. 117. *Praxibulus laminatus* (Stål), Canberra, A.C.T., Australia.
Fig. 118. *Romalea microptera* (Beauvois), source (?).
Fig. 119. *Schistocerca alutacea* (Harris), Iowa.
Fig. 120. *Schistocerca americana americana* (Drury), Waxahachie, Texas.
Fig. 121. *Schistocerca gregaria* (Forskål) phase solitaria, Wachiro, Eritrea.

Plate XVIII

Subfamily Cyrtacanthacridinae

Fig. 122. *Schistocerca gregaria* (Forskål) phase gregaria, Anti-Locust Research Centre, London, laboratory-bred.
Fig. 123. *Schistocerca lineata* Scudder, Wilmer, Texas.
Fig. 124. *Schistocerca* sp., Yurimaguas, Peru.
Fig. 125. *Tetrataenia surinama* (Linnaeus), Yurimaguas, Peru.
Fig. 126. *Thisoicetrus annulosus* (Walker), Wachiro, Eritrea.
Fig. 127. *Urnisa guttulosa* (Walker), Canberra, A.C.T., Australia.

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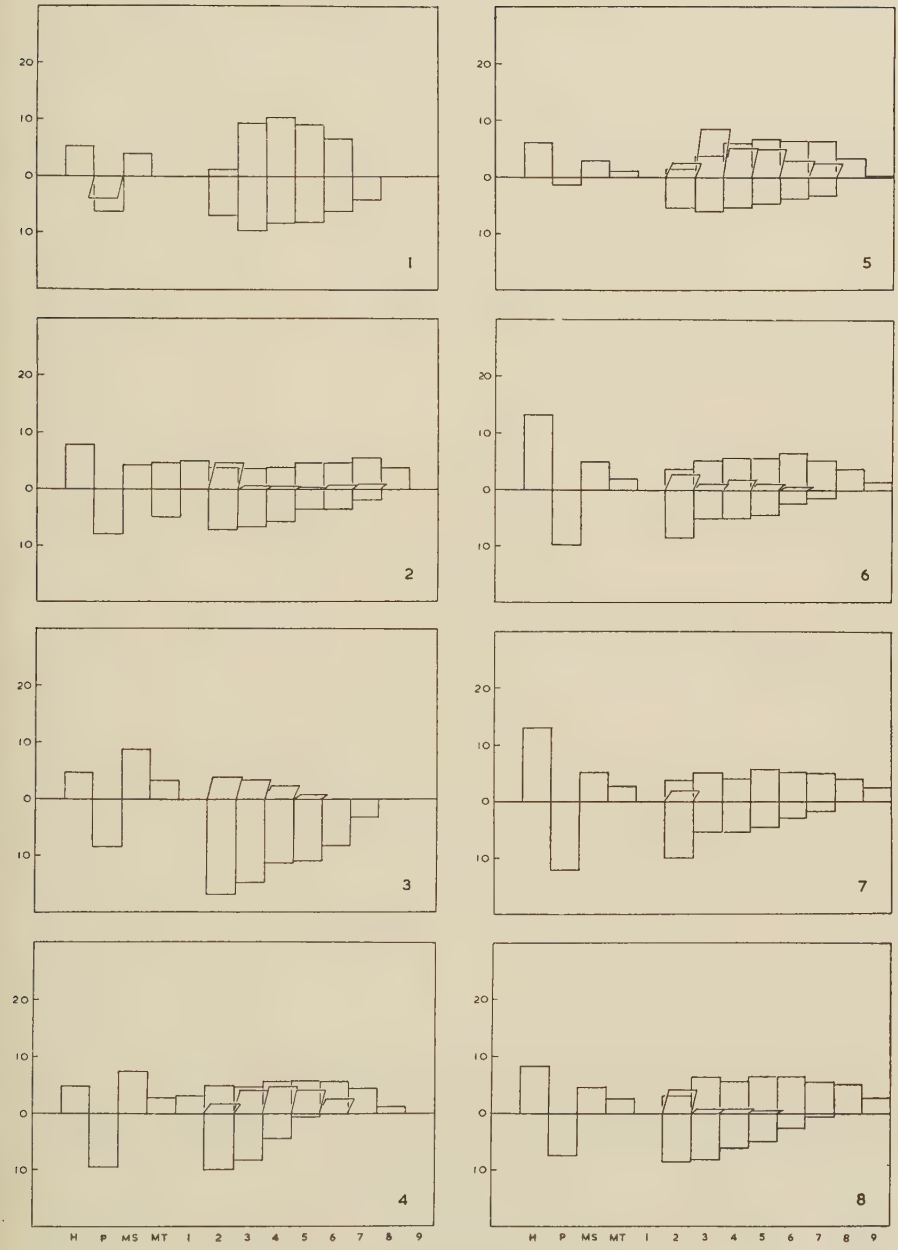

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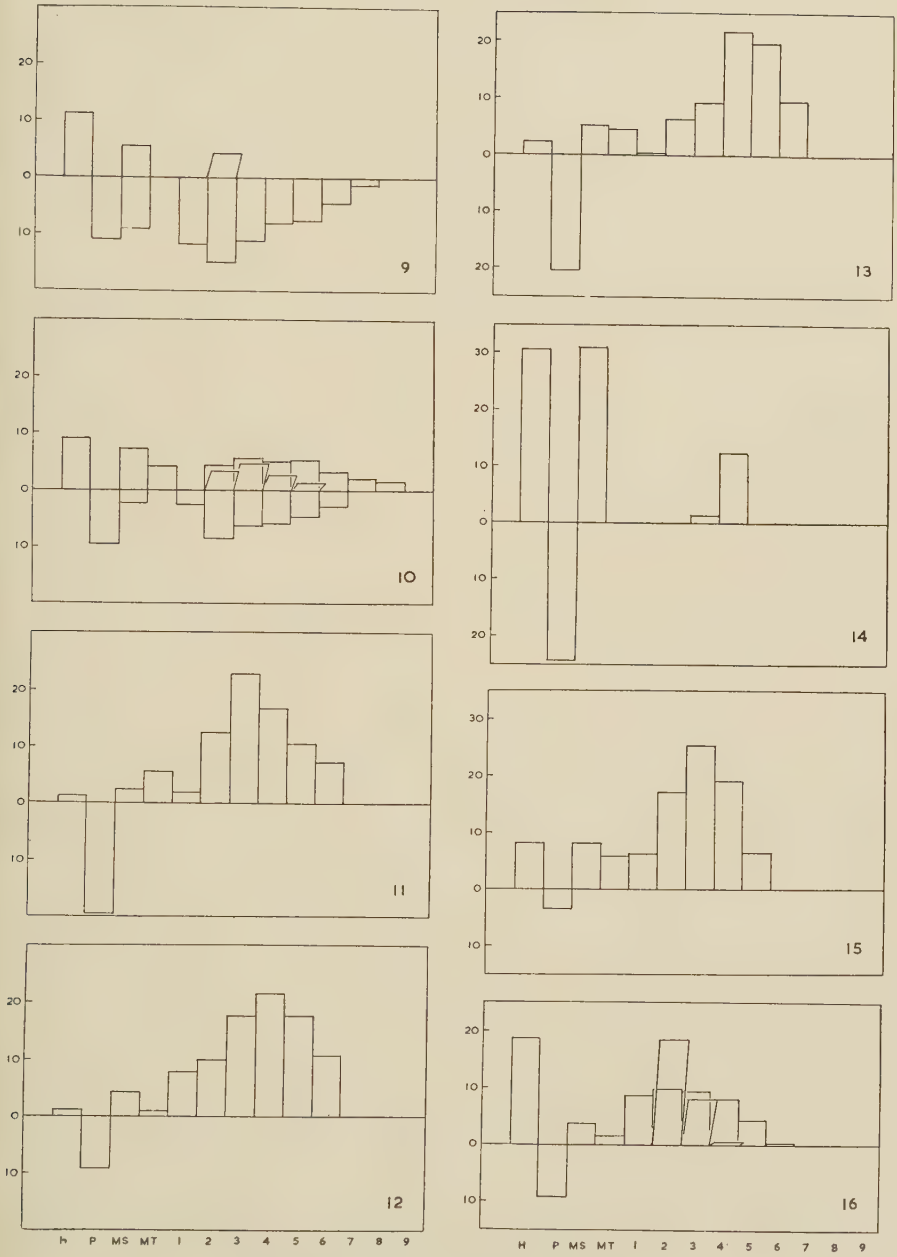

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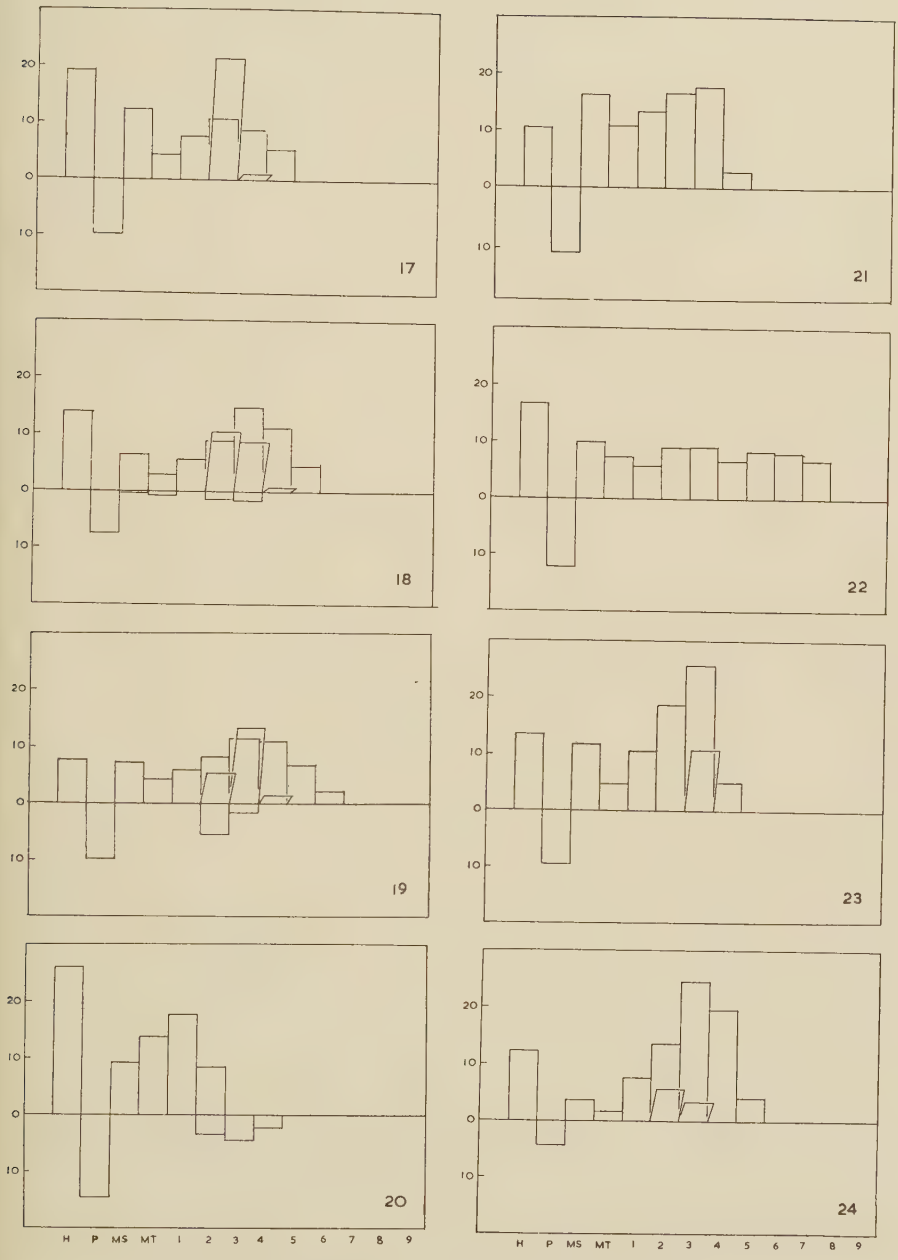

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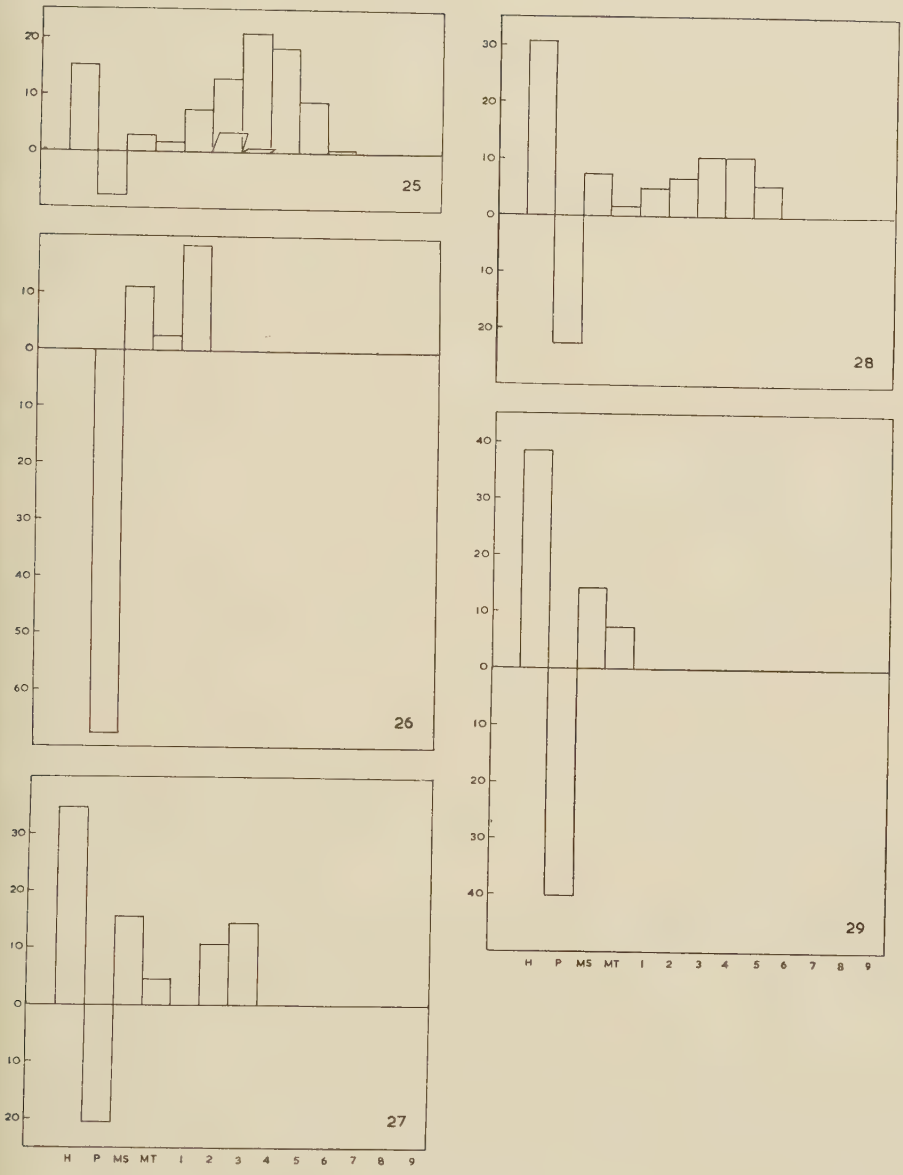

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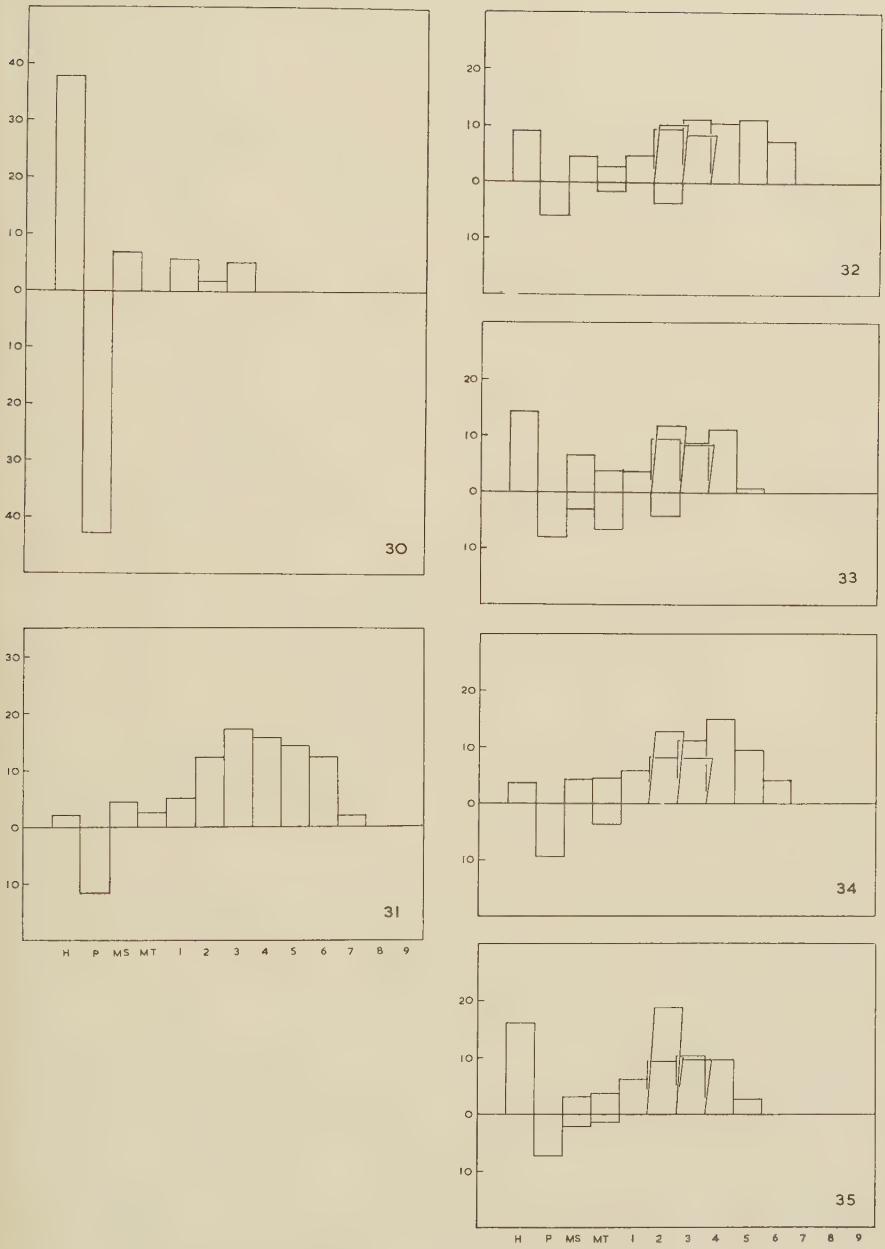

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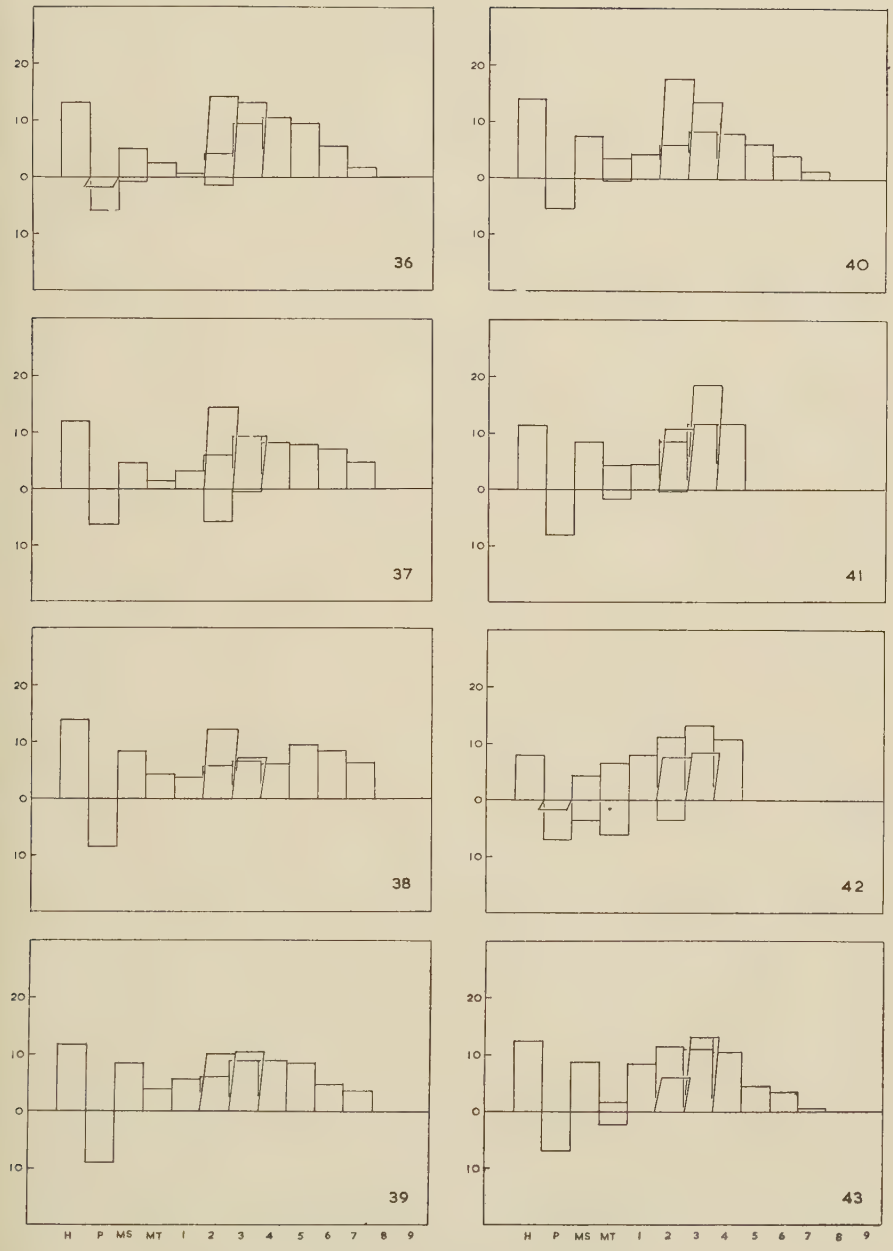

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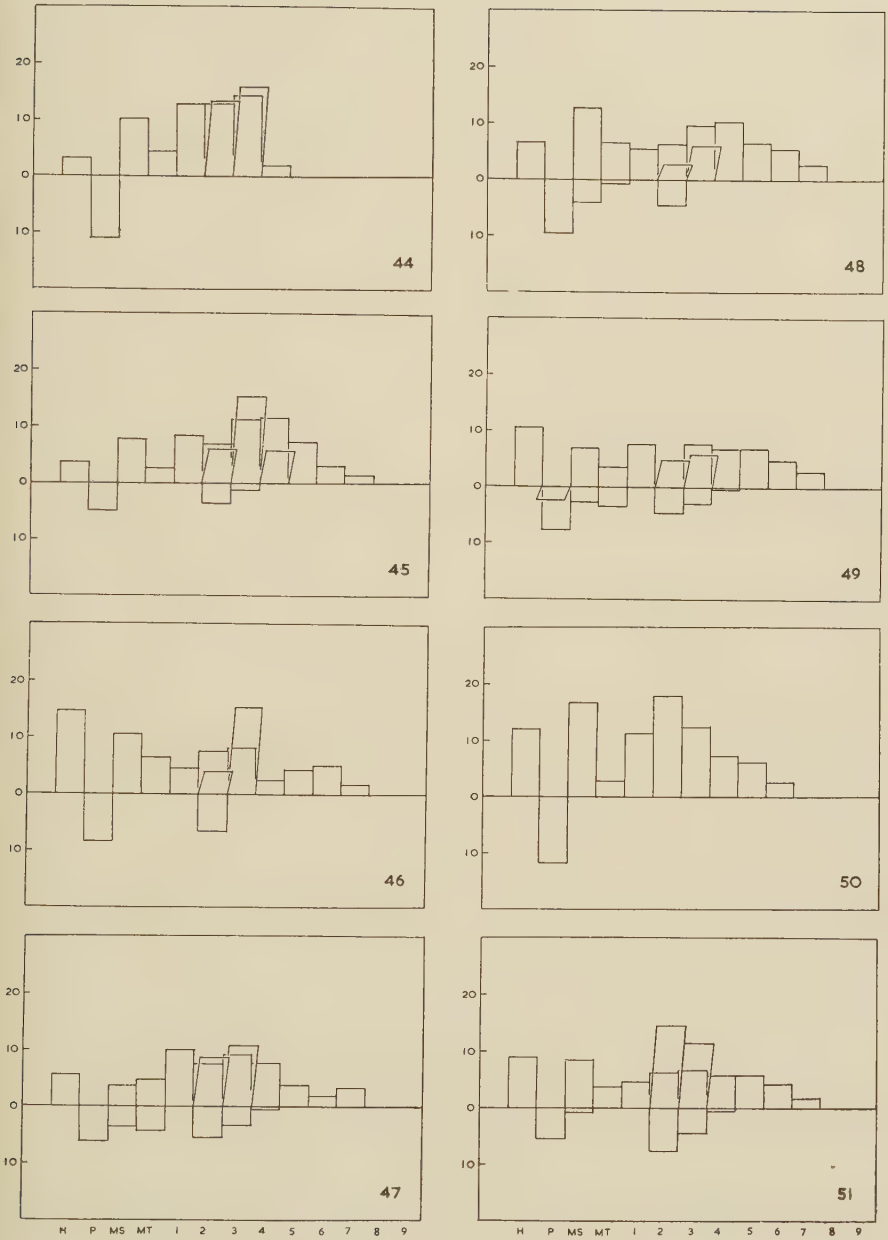

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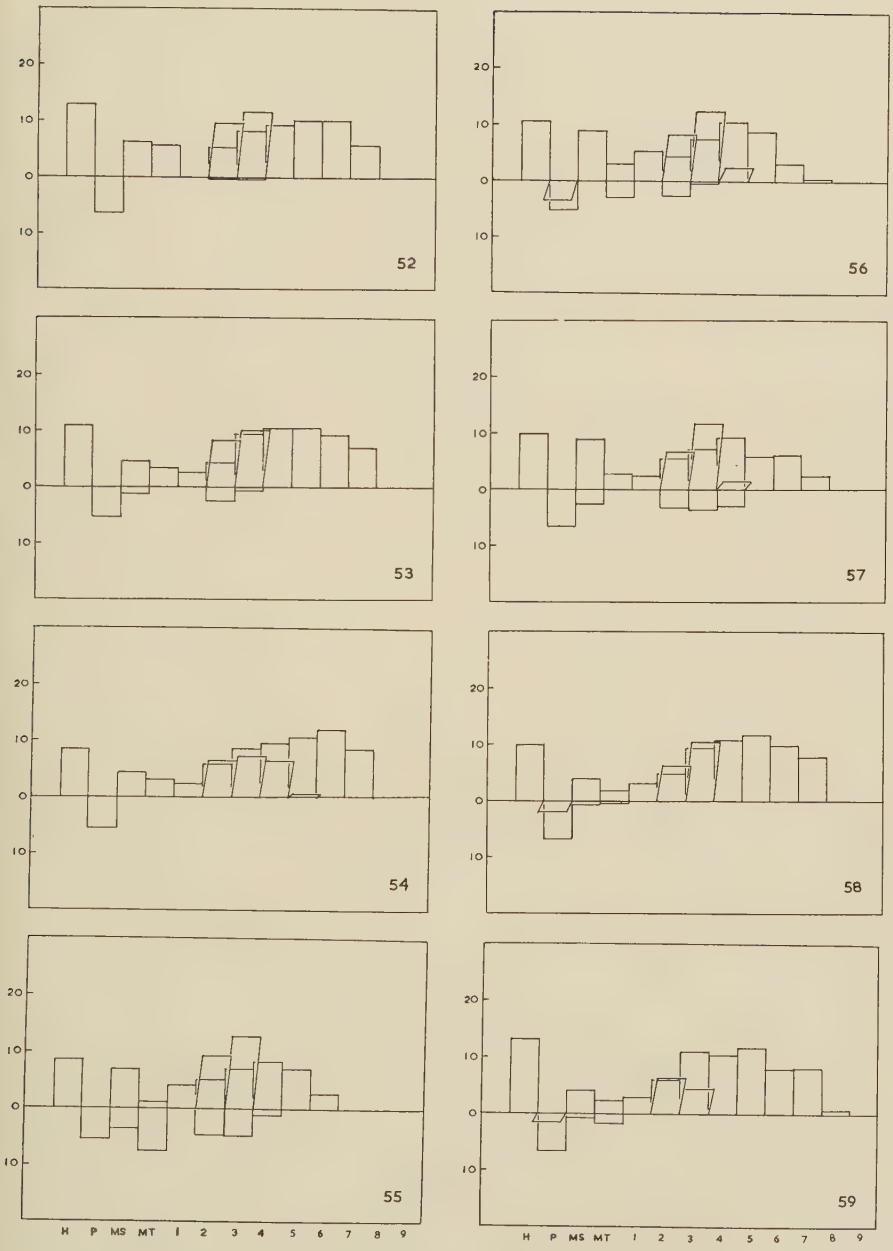

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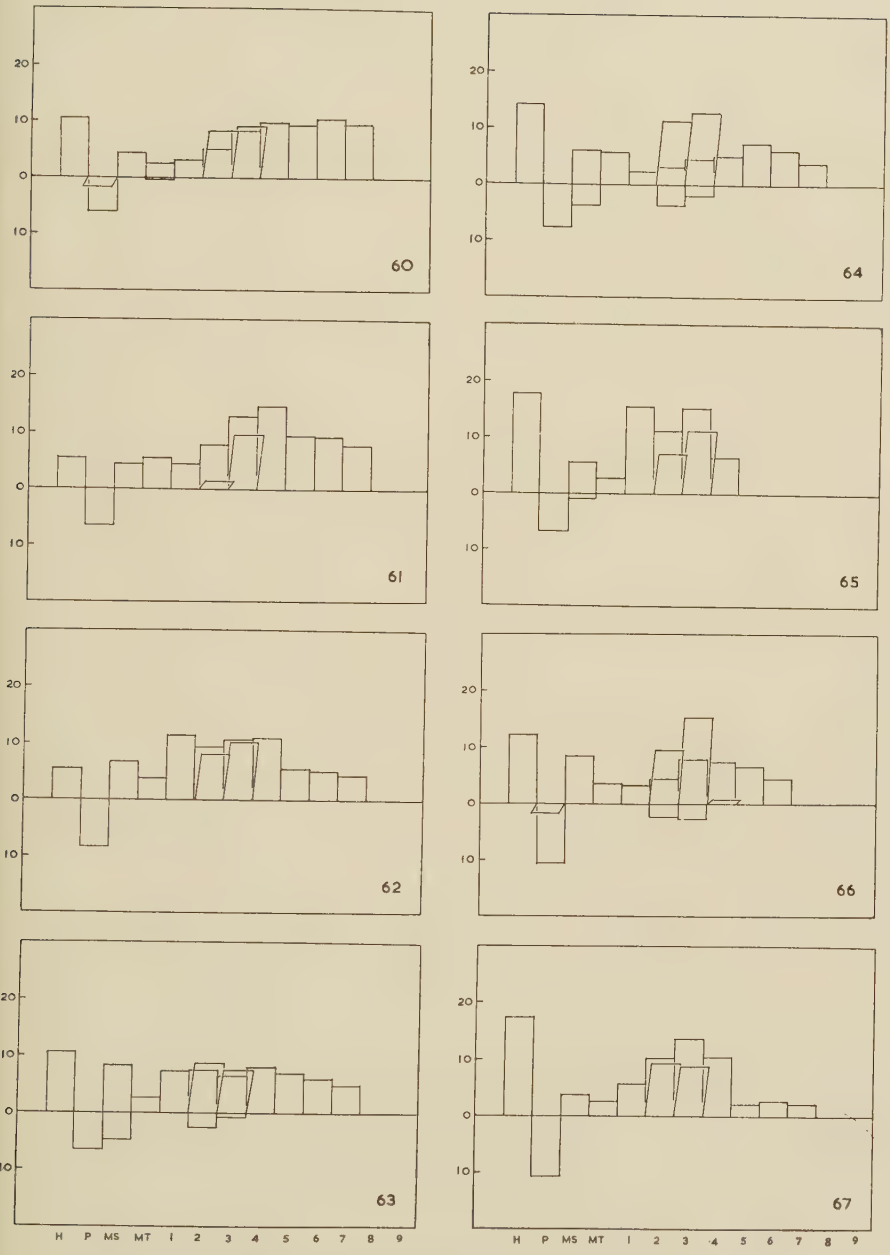

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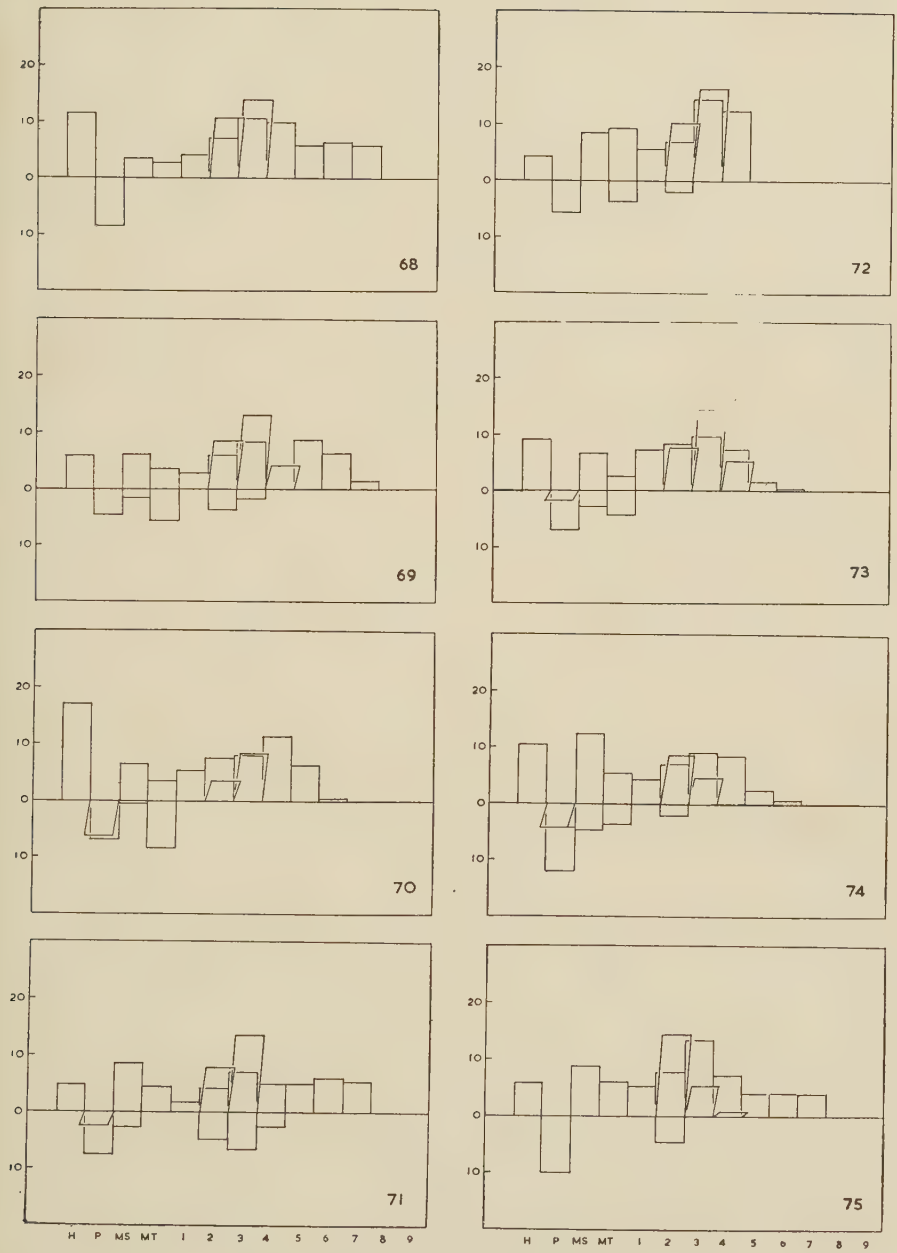

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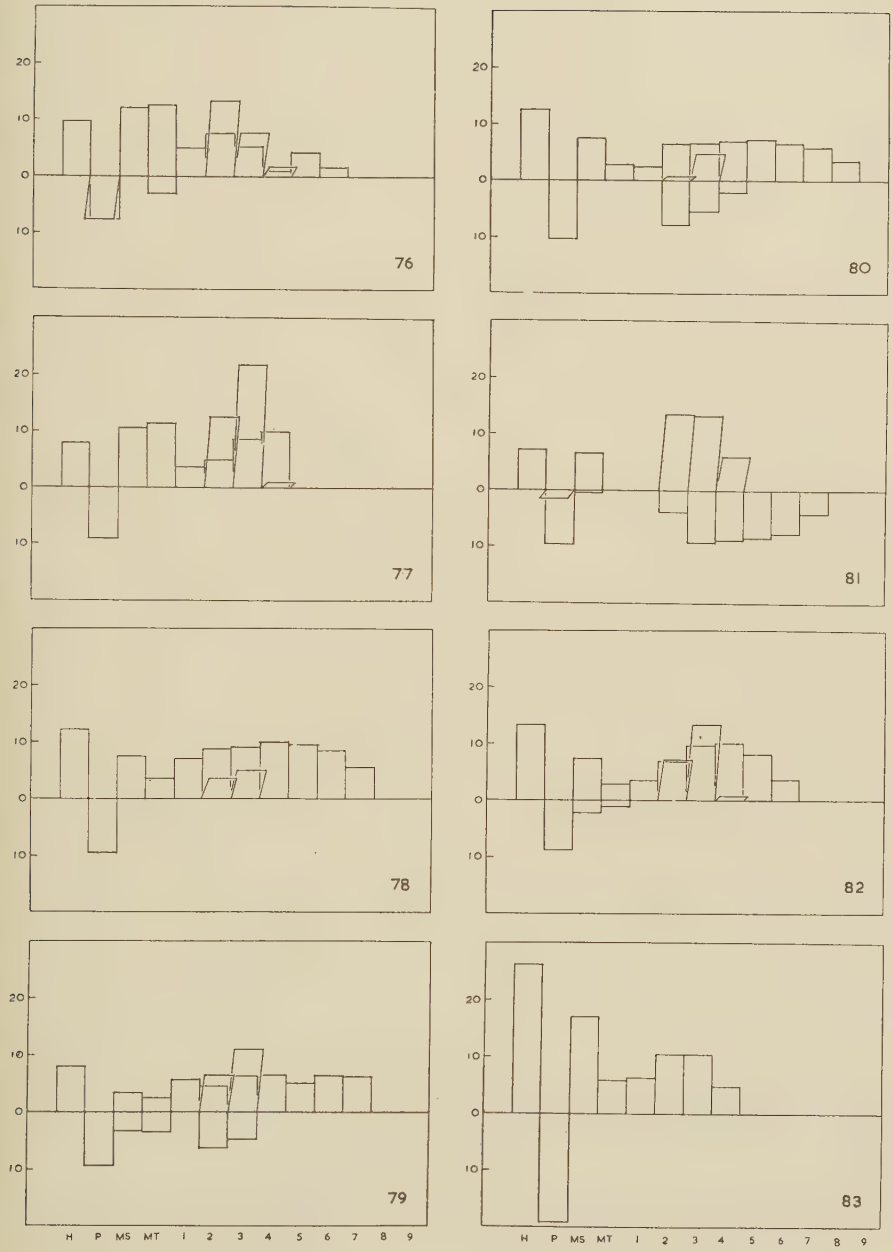

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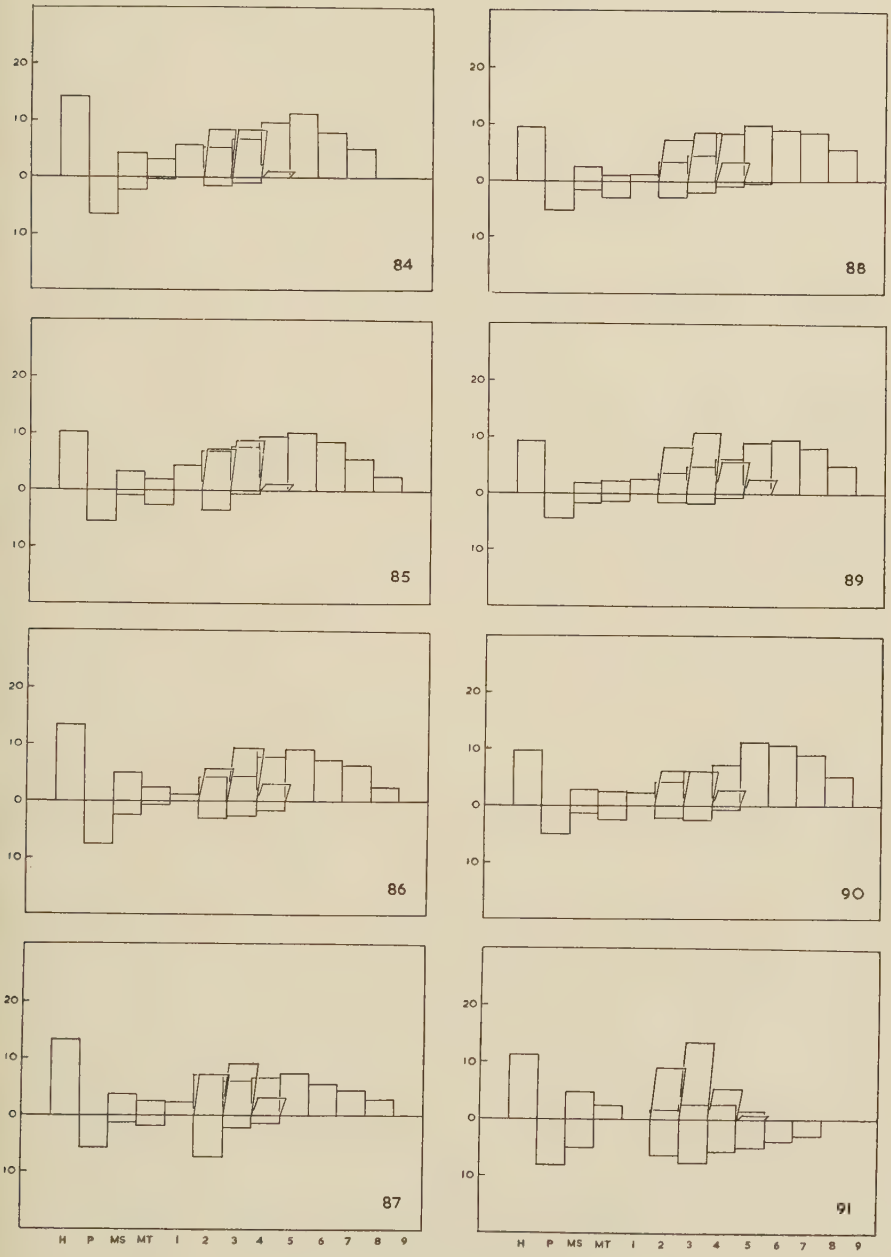

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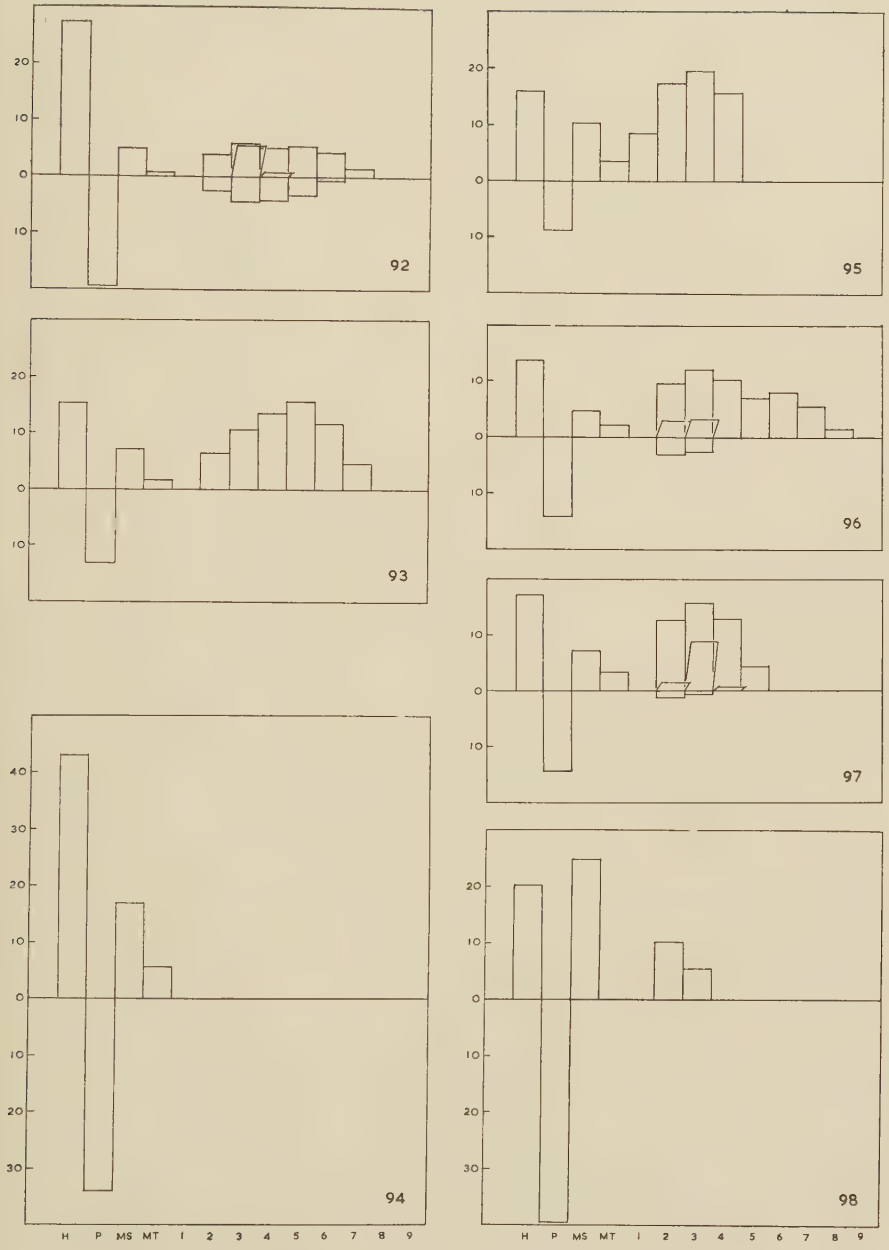

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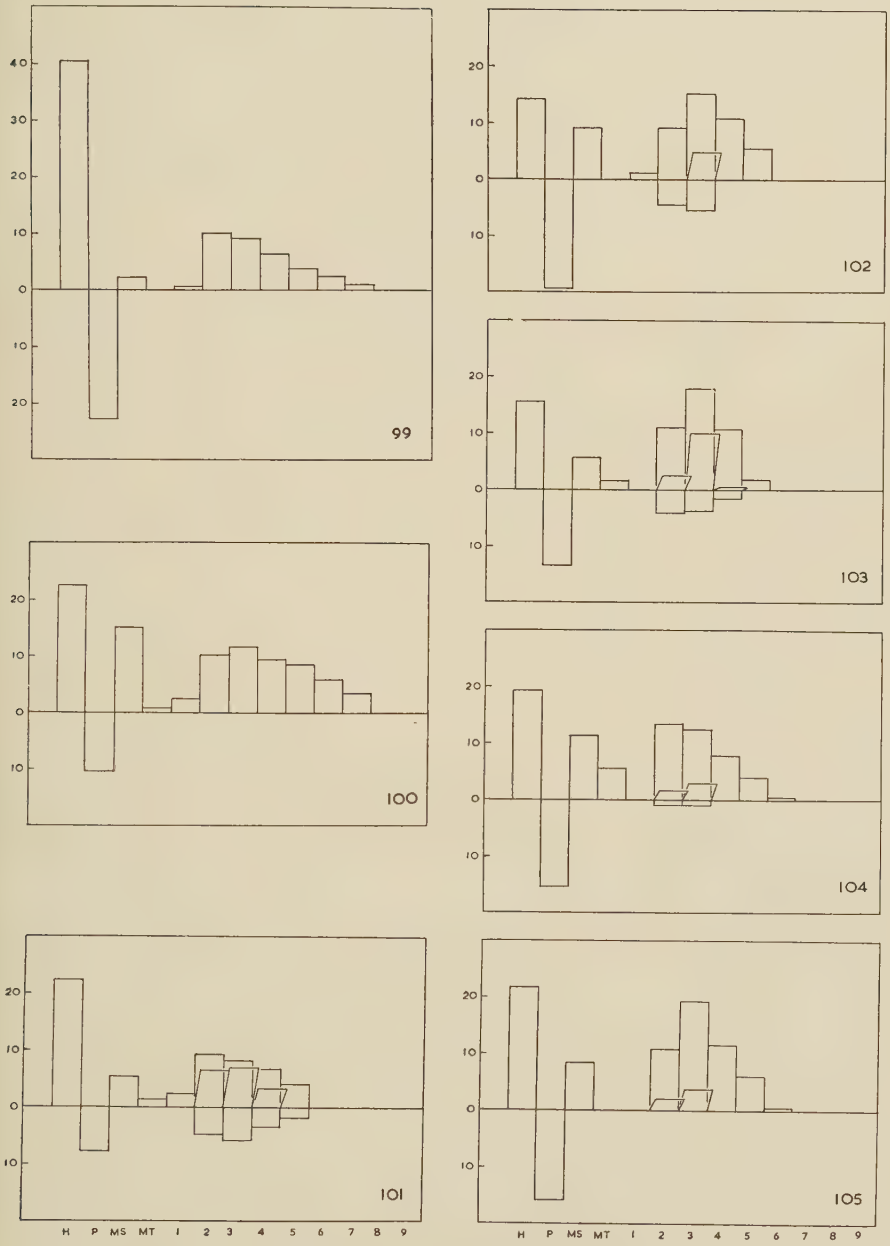

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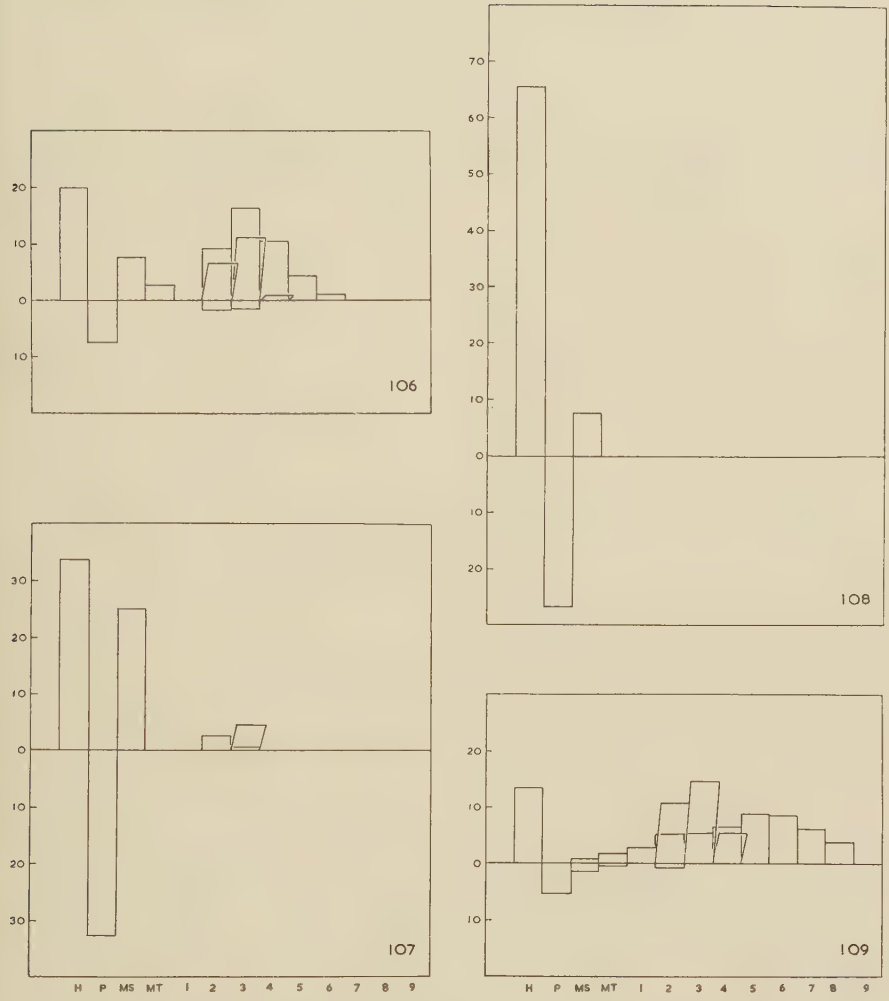

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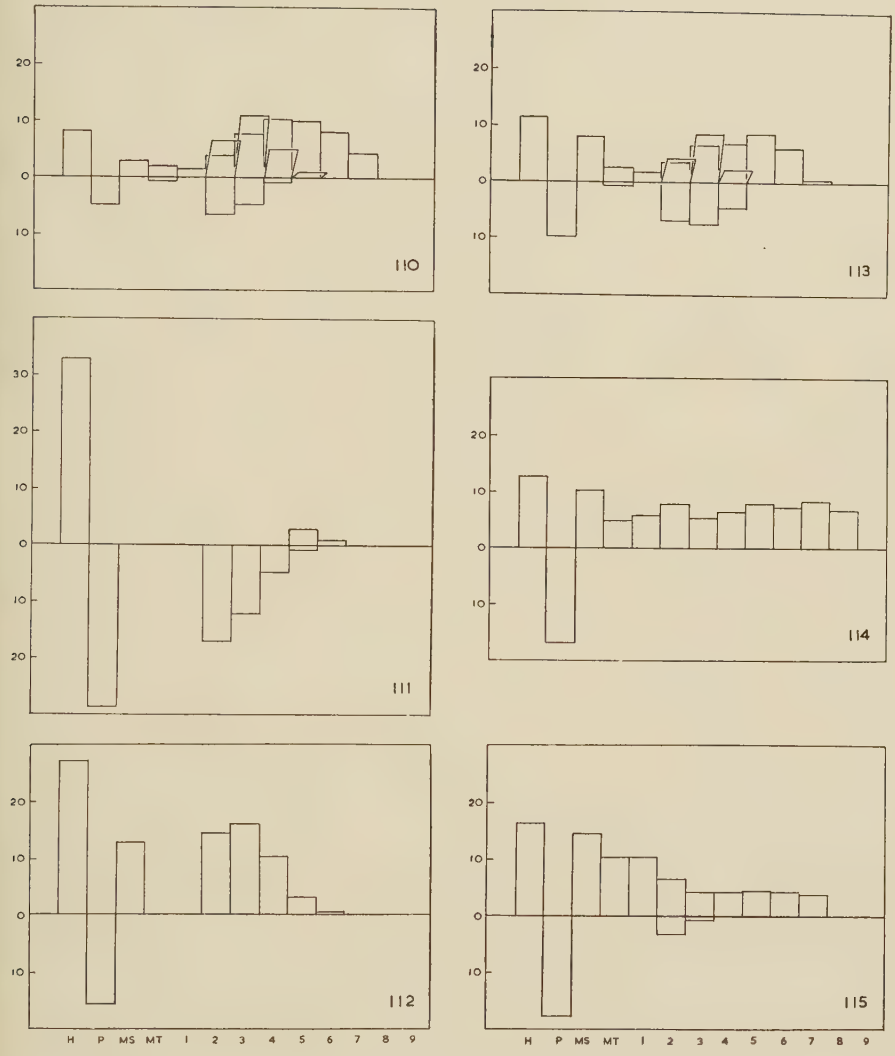

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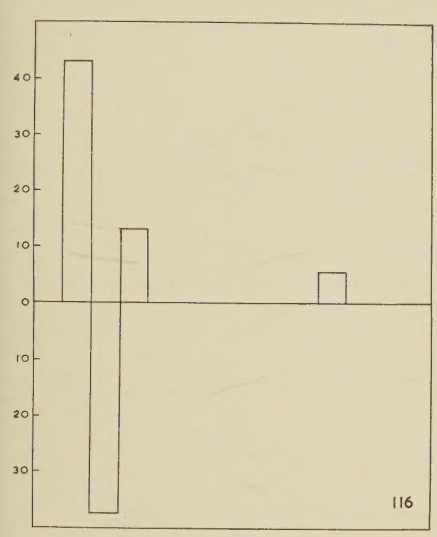

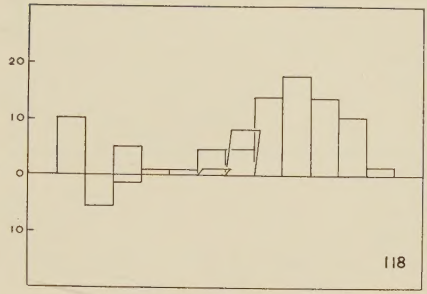

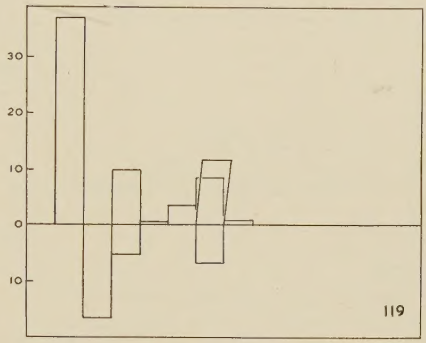

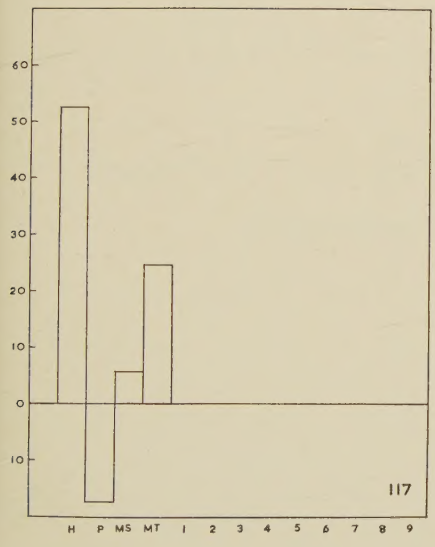

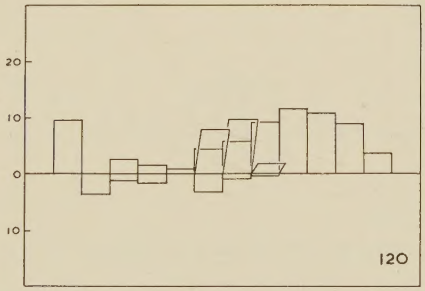

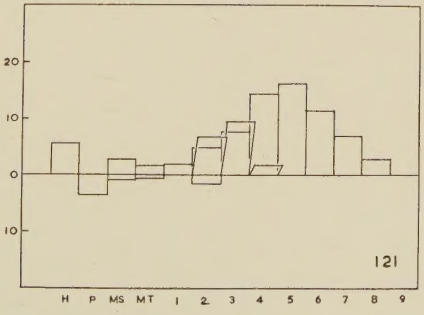

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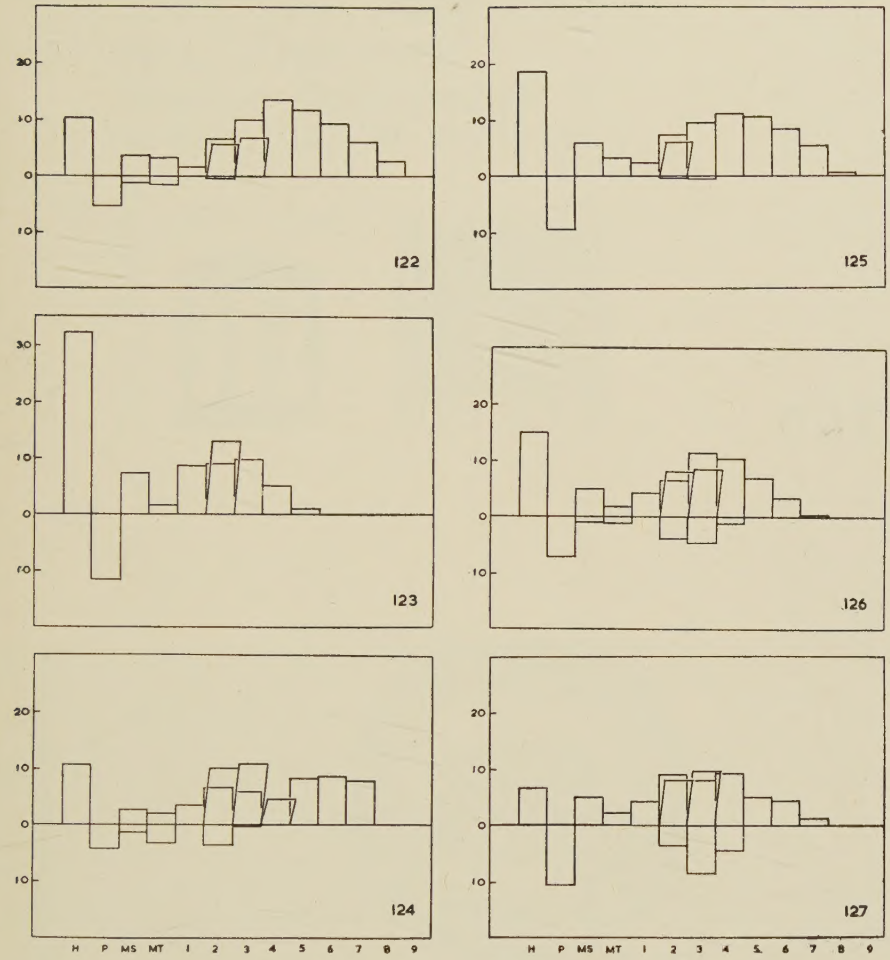

SLIFER—HEAT SENSITIVE AREAS